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ABSTRACT

TO ASSESS STATIC BALANCE ABILITY IN CHILDREN 239 SUBJECTS (AGES 5 TO 9) WERE TESTED USING A TECHNIQUE OF ELECTRONIC ATAXIAMETRY. BODY WEIGHT DISPLACEMENT WAS MEASURED FOR VARIOUS POSTURES. THE SCORES CORRELATED SIGNIFICANTLY WITH TEACHER'S EVALUATION OF SCHOOL PREPAREDNESS, BASIC MATH SKILLS, AND READING ACHIEVEMENT IN SAMPLES OF NORMAL CHILDREN. GIRLS WHO RANKED HIGH IN STATIC BALANCE ABILITY IN COMPARISON TO BOYS SHOWED HIGHER SCORES WITHIN SEX GROUP CORRELATIONS BETWEEN EQUILIBRIUM CONTROL AND BETWEEN SCHOOL AND READING READINESS. THIRTY-THREE EDUCATIONALLY HANDICAPPED STUDENTS WHO HAD SLIGHTLY LOWER STATIC BALANCE SCORES IN POSTURES WITH OCCLUDED VISION WERE EFFICIENTLY DIVIDED INTO BALANCE IMPAIRED AND BALANCE UNIMPAIRED GROUPS. INDICATIONS WERE THAT THE STUDY APPEARS TO ADD TO THE KNOWLEDGE OF THE ROLE OF MATURATIONAL AND ORGANISMIC FACTORS IN LEARNING DIFFICULTIES IN BOTH NORMAL AND EDUCATIONALLY HANDICAPPED CHILDREN IN PRIMARY GRADES. EXTENSIVE TABLES OF RESULTS ARE INCLUDED. (AUTHOR/JM)

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PREFACE

This project was conducted at the Department of Pediatrics and Human Development of Stanford University School of Medicine whilst the principal investigator was on Sabbatical Leave from the Hebrew University of Jerusalem. We wish to acknowledge the devoted collaboration of Mrs. Noemi Wagner in carrying out this study and the assistance of Miss Margarete Ashly in conducting the ataxiametric experiments. We thank the School District Research Directors Dr. Bruce Keeper and Dr. Leroy Porter, the School Principals, Mr. John Papagni, Mr. Don Johnson and Mr. K. McCarthy as well as the teachers and the staff of Hoover School, John Gill School and Taft School for their efficient cooperation in organizing the examinations and providing the subjects. We are much indebted to Mr. Geoffry Buck, representative of the N.A.S.A. Biomedical Research Assistance and Utilisation Program who helped and advised us during the first decisive phases of the program. Thanks are due to Dr. Harry Jennison, Medical Director of the Stanford Childrens Convalescent Hospital for his guidance in organizing the study and to Mrs. Lindo Marrachine and Mrs. D. David Forsythe who assisted in carrying out our pilot examinations.

SUMMARY

Developmental patterns of static balance ability in children at ages 5-9 were assessed by using a technique of electronic ataxiametry, consisting in the measurement of body weight displacement by pressure transducers, mounted to four footplates, each to bear one heel or toe part. The obtained fluctuation and weight displacement scores for various postures, none lasting more than 20 seconds, turned out to correlate significantly with teacher's evaluation of school readiness, basic arithmetic skills and reading achievement in samples of normal school children (1 Kindergarten, 2 first grades, 2 second grades and 1 third grade, total N=206). Girls who were precocious in static balance ability in relation to boys, tended to show higher within sex group correlations between equilibrium control and between school and reading readiness. A sample of 33 undifferentiated Educationally Handicapped pupils at age 9, having a generally but not significantly lower static balance ability in postures with occluded vision, was efficiently dichotomized by ataxiametric scores into balance impaired and balance unimpaired subjects. The study seems to throw new light on the role of maturational and organismic factors in the etiology of learning difficulties in normal and educationally handicapped children at the primary grades.

INTRODUCTION

Static balance ability is essentially the capacity to maintain the typical human, upright posture under various (sometimes stressful) circumstances without any overt displacement of the feet and without any other part of the body (besides the feet) touching a supporting object or surface. This function must be differentiated from keeping equilibrium whilst in motion, as for instance, when walking on a rail or climbing a tree. Actually, factor analysis has repeatedly shown that "static" and "dynamic" balance are represented by different factors of motor ability. (Fleishman,1962) Thus, a child who seems to demonstrate good motor skill in riding a bicycle or in jumping over fences may still have difficulty to stand on one foot without moving.

The anatomical, physical, physiological and psychological aspects of the human body's static equilibrium have been extensively investigated by scientists from various disciplines, applying different methods and techniques. Medical research has tried to elucidate many neuro-physiological and physical factors involved in the act of standing, namely: muscle activity (Joseph, 1960; Mann & Inman, 1964); the location of the center of gravity and its displacements (Akerblom, 1948); the function of the vertebral column (Leger, 1959), the constellation of physical forces acting upon the ankle joint (Smith, 1957); the influence of sex and aging (Boman and Jalvisto, 1953); Hellebrandt & Braun, 1939); neurological correlates (Fearing, 1924); the mechanisms of the foot (Hicks, 1953, 1954);reflexological aspects (Hellebrandt, 1938); effects of temperature (Orma, 1957), etc.

Recently aerospace and naval medicine is giving increasing attention to problems of static balance (Graybiel and Fregly, 1966; Fregly & Graybiel, 1968). Relative to this wealth of investigations, medical research concentrating on developmental changes in the neurophysiological mechanisms of standing seems to be scarce, whilst the anatomical problems of postural habits in children have evoked considerable pediatric interest. (For an overview on this subject see Leger, 1959).

Psychological and educational research (and in the latter domain especially research in physical education), has been mainly concerned with strictly behavioral aspects of static equilibrium control. Some early publications on this subject date back to the beginning of the century (Hancock, 1894). Systematic data on the developmental patterns of static balance ability have been published by Oseretzki (1931) and by Sloan (1955). Norms for adolescents and young adults have been recently provided by Fleishman (1962) and for young children by Holbrock (1953), Kohen-Raz (1965), Stott (1968) and Keogh (1965, 1968). The main objective of psychological and educational research has been the establishment of developmental norms in order to predict physical performance and success of physical training. Recently systematic attempts have been made to investigate the impairment of balance in retarded and handicapped children. (Stott, 1968; Keogh and Oliver, in press).

All developmental studies report unanimously the precocity of girls in static balance ability and a steep developmental progress between the ages 5 to 8, which occurs somewhat later in boys.

Several methods of measuring static balance ability are described in the above cited literature. The simplest and most straightforward way to assess equilibrium control is to measure the time of maintaining a certain posture without moving the feet or taking resort to support. This method is used in developmental tests of motor ability (Oseretzki, 1931; Sloan, 1955; Fleishman, 1962; Kohen-Raz, 1965; Stott, 1968; Keogh, 1968). Although apparently reliable in older subjects, the relatively short timed pass/fail scores are of questionable reliability in children under the age of six. This approach has the additional disadvantage of measuring the incidence of failure instead of assessing the patterns of performance. More sophisticated methods are based on the use of devices, called ataxiameters or statometers. The principle of these methods consists in recording body sway, transmitted by means of a stylus attached to the head, hips or back or mounted to footplates. (Hancock, 1894; Skaggs, 1932; Seashore, 1938; Smith, 1957). A peculiar machine has been constructed by Miles (1922) who used a headpiece attached to four mechanical counters, one for each direction of sway, (forward, backward, left and right). A rather complex statometer, combining a mechanical and electronic output system has been employed by Akerblom (1948). All these devices have been used foremost in laboratory experiments with adults, whereas children in field settings were examined by the simpler methods of presenting timed test items.

OBJECTIVES OF PRESENT STUDY

It will be noted that most of the cited studies tend to explore a rather narrow and closed system of variables within the frame of reference of a more or less intra-disciplinary problem: such as the constellation of physical vectors, variations in the electromyogram as a result of postural changes, relations between sex, age and body sway, effects of intoxication on steadiness, etc.

At certain variance with these approaches it was the main purpose of this study to cover an inter-disciplinary border area between neuro-physiological and behavioral research, namely to make an attempt to use the ataxiametric variables as a bridge between a strictly sensori-motor, close-to-reflex-level and therefore presumably neuro-physiologically rooted response system, and the system of higher cognitive responses, involved in complex mental achievements. The more limited and definitive aim of the study was to test the hypothesis that static balance ability represents a basic factor in the development of mental abilities which are pre-requisites for school entrance, such as the correct perception of complex geometrical figures, basic manipulations of numbers and the ability to read and write.

The general basis for this assumption, that equilibrium control should be related to cognition, is the well documented observation, made by authors in the field of neurophysiology, psychiatry and psychology, that the state of consciousness, which is the necessary pre-condition for higher mental performances, is intimately linked to static balance ability, as obvious in cases of brain damage and states of intoxication.

However, it would be erroneous to assume that this relationship is one of a sufficient, or necessary cause and effect.

This limitation of causal relationship is evident in somnabulic or hypnagogic states during which static balance may be perfectly sustained, whilst conscience is lowered or eliminated. Furthermore, acrobats with excellent equilibrium control are not necessarily very intelligent. On the other hand, paralyzed subjects, unable to keep balance may possess high mental competence.

Actually it must be emphasized that our hypothesis is strictly developmental,* in that we propose to examine the role of static balance ability in cognitive growth during certain critical phases of development, such as the transition period from kindergarten to school. (Other such periods may exist, for instance the stage when the infant rises himself from sitting to standing,** or during the adolescent growth spurt). The major assumption is that during these phases, a general process of intensified brain maturation effects physical and mental growth, as well as induces an increase and improvement of equilibrium control. Before and after these

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*For a comprehensive theory of developmental interaction between physiological, psychomotor and cognitive functions and further relevant references see Rothschild (1961).

**Some relevant findings in this respect have been recently published by the principal investigator. (Kohen-Rax, 1967, 1968).

"growth thrusts," the relationship between static balance and cognition may drop to insignificant levels or vanish altogether. It may turn out that such assumed "temporary liaisons" between neurophysiological and mental functions may represent a fundamental developmental principle. Its ignoration may mislead the investigator to search for an overall, age-independent relation between mental and physical growth, and when he fails to discover it, he erroneously concludes that the relation is non existent.

Metaphorically this principle may be compared to the relation between a wooden plank and a sea wave, drifting it ashore. At a certain moment the wave carries the plank and both, wave and wood move in common sway. However, after a while, the wood is left behind and follows its course, whilst the wave splashes ahead. In a similar way, a physiological process may stimulate the growth of a mental function at a certain moment of development, "carrying it on its back," so that a common growth spurt appears in both functional areas. However, later on their growth rhythm and impetus disengage and diverge, and both follow independent patterns of development.

Even within the limits of our developmental hypothesis, it should be stressed, that static balance ability may represent only one factor, though possibly an important one, of cognitive school readiness.* This means that a fair number of cases may exist, whose static equilibrium is perfectly normal, but their failure to adapt to school stems from psychogenic conflicts or socio-cultural disadvantage. On the other hand, children with low balance control may be of normal mental ability, although these latter instances may be rarer than the former. Still, such findings would be compatible with the emergence of significant correlations between equilibrium and mental variables, indicating that cases of learning difficulties may be classified into low achievers with possible constitutional, organismic or maturational deficits, which are manifest in impaired balance, and into those who are educationally handicapped because of purely psychological or sociological factors. In the latter case equilibrium would be normal. But even such a finding would justify the effort to test our hypothesis, besides the theoretical importance of throwing more light on tangible patterns of "nature-nurture" interaction. This theory of interaction is widely accepted as a general principle, but lacks specific content, so that any demonstration of such interaction in the form of factual, measurable processes is important to the investigator and practitioner in the field of psychology, pediatrics and education.

Besides testing the main hypothesis, it was the aim of the study to elaborate a method of electronic ataxiametry (which will be described in detail below). This method was supposed to meet the following demands and criteria:

*For a detailed presentation of the problem of intrinsic relations between motoric and cognitive school readiness see Kohen-Raz (1965).

a. It should yield reliable and objectively measurable data of performance patterns, in contrast to the crude pass/fail criteria of the traditional testing procedures of static balance ability.

b. It should be possible to use the method in laboratory settings as well as in the field, i.e. in school premises, where large populations of students can be tested.

c. The administration procedure should be eas short and keeping the child alert and motivated.

An additional pragmatic aim of the study was to widen the basis for interdisciplinary activity between the pediatrician, the developmental neurologist and developmental psychologist, and to facilitate the cooperation between the medical, psychological and educational school personnel.

THE METHOD OF ELECTRONIC ATAXIAMETRY

Apparatus and procedure

The principle of electronic ataxiametry is the measurement of body-weight distribution, whilst the subject stands on four foot-plates provided with electronic pressure transducers. Each plate supports one heel and one toe part of the two feet respectively. The heel and toe plate are fixed one behind the other, so that there are actually two plates, one for each foot, which can be freely moved and adapted to various forms of postures, such as "stand at ease," "heel to toe" etc. Whilst the sum of pressures recorded by the transducers on the four plates approximates the total weight of the subject, the distribution of pressures over the fourfold set plotted against time, shows fluctuations of weight displacements, which reflect the amount and direction of sway in forward-backward and left-right direction. In addition, the average percentage of weight placed during a certain period on one, two or three plates can be computed, indicating the tendency of the preferred location of the center of gravity in relation to the supporting area.

When the subject stumbles, steps off the plates or takes resort to arm support, the pressure on the footplates decreases abruptly and the failure is thus easily detected in the record of the electronic output.

The transducers are mounted in a way which makes them minimally sensitive to horizontal weight displacement and maximally sensitive to vertical pressure. This technical detail is important, as otherwise the exact location, form and seize of each foot would have to be measured, which would render the method impracticable. On the other hand the insensitivity of the plates to horizontal shifts makes it possible to achieve an easy and simple control of the foot position by placing the ankle bone (lateral mallelus) above the dividing line between the front and rear plate. In such way the dividing line passes below the arch of the foot, which is a satisfactory criterion to ensure a fair front/back dichotomy of foot pressure.

Using electronically sensitive foot-plates, especially with children, would still be a questionable technique, as any wiggling, turning around and movements of hand and neck result in changes of weight distribution liable to produce artifacts in the record. Besides this, stepping on the plate causes violent deflections, so that some time is needed to establish a "quiet" base line as a frame of reference for the actual performance of maintaining equilibrium. In order to control optimally these factors the following essential parts were added to the foot-plate set.

a. The "feed-back device" consists in a series of 16 lights and bells, which lighten and sound in synchrony at regular intervals from the beginning to the end of each experimental period lasting 20 seconds per equilibrium-test item. The lights have various colors and are mounted vertically on a piece of embedding material.

The bulbs lighten from the bottom to the top, as if reflecting the "mounting effort" required to keep balance. The bells play a structured tune, also suggesting "mounting." Besides being an additional attraction, the bells provide feed-back during the blindfolded positions. The child who is instructed to keep his balance until the top bulb lightens and the tune is finished, is strongly attracted by the ongoing spectacle and keeps optimally still and attentive.*

b. Arm support is provided by two horizontal bars placed at a distance of 4 to 5 inches from the child's hips. Their height and distance can be adjusted to the individual seize of each subject. Whilst stepping on the plates, the child is asked to hold the bars until the Examiner gives the command to leave the handles and to put the hands on the hips. The removal of the arm pressure from the handles starts the play of the lights and bells and also activates an electronic pen marking the moment of shifting the total weight onto the footplates. If the child takes resort to arm support, touching the bars automatically stops the music and lights, whereas regaining balance and leaving the bars reactivates them, whilst the failure is electronically recorded.

These devices, besides producing records of a base line, of starting and end points of the experimental period, as well as of moments of failure to maintain equilibrium, motivate the child to keep a relative steady position and to abstain from voluntary turns of neck and trunk. In addition, the handles give the child a feeling of security, specially during maintaining the more difficult postures.

The ataxiametric test-battery

The choice of postures to be used as ataxiametric test-items is wide and many dimensions of stress and difficulty can be induced, such as 1) extended time of balance maintenance, 2) occlusion of vision, 3) restriction of the support area (by standing on one foot, heel to toe, on tiptoes or by narrowing the width of the plates,) 4) tilting the supporting platform, 5) balancing objects whilst keeping equilibrium, etc. On the other hand, an important requirement of any ataxiametric test battery to be administered to children is its brevity. Even with the use of our spectacular feedback devices, fatigue and boredom may show up and introduce intervening variables which are difficult to control. There are some additional features of test construction and administration which have to be considered:

The more difficult items should be interspersed among the easier ones and not appear either at the beginning or the end of the test. Occlusion of vision must be postponed until the child has adapted himself to the experiment. Whilst it is impossible to rely

*Experience has shown that the children were fascinated by the device and are eager to watch the play being repeated well beyond the time they were expected to remain task oriented.

on the child to close his eyes, imposed blindfolding might have adverse effects on motivation. It was therefore decided to ask the child to wear a pair of sunglasses wrapped by a large vision-occluding paper tissue. This technique has the advantage of being familiar to the child and amusing. It is also hygienic, because the paper tissue can be easily changed.

Taking into account all these and other considerations, a temporary battery was designed, which obviously is still far from being a final and optimal form of an ataxiametric test. However, it seems to fulfill the requirement of brevity, whilst still covering an essential variety of postures.

The experimental period for each item was 20 seconds, which is long enough to yield an evaluable length of ataxiametric record, without producing excessive strain. Rest periods between items varied between 10 seconds to one minute, during which the postures and positions of the plates were changed. It seemed not to be advisable to fix exact time limits of rest periods, as this would have induced more tension than additional experimental control.

The final selection and sequence of items was as follows:

1. Standing normally with eyes open. The plates are placed one besides the other, without any space left between them. This forces the Subject to stand with his feet parallel and close, which is not as usual a posture as it may appear. (Other investigators used more "comfortable" positions as representative postures of normal standing, such as stand at ease, toes apart, etc.) This is a convenient posture to start with and is actually used chiefly in order to familiarize the Subject with the apparatus and the procedure.

2. Standing on left and right foot respectively, with eyes open. This posture involves considerable stress, but as eyes are kept open, children readily perform it.

3. Standing normally, blindfolded. This is the same posture as item 1, except for vision being occluded by blindfolding the child as described before.

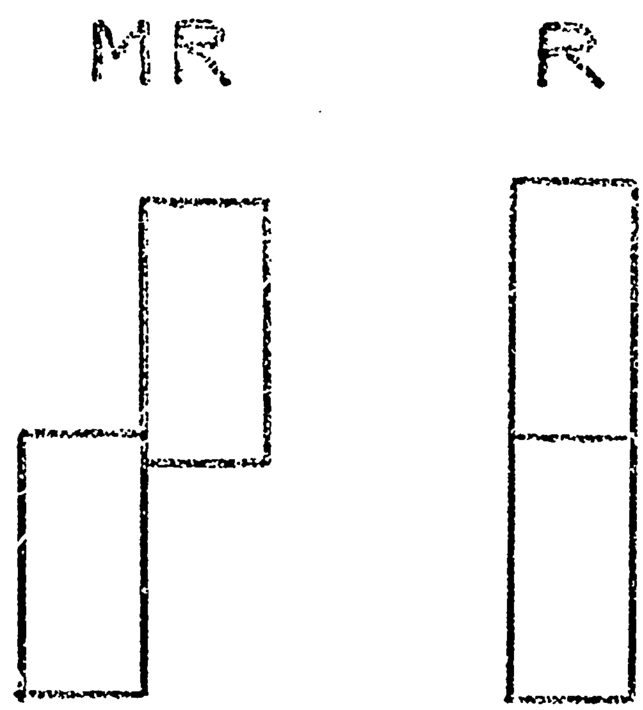
4. "Modified Romberg" Position, eyes open. This posture is midway between normal standing and the Romberg (heel-to-toe) position, in that the heel of the right foot is placed to the right side of the left toe, as depicted on Figure 1 a. This requires shifting of the footplates.

5. "Modified Romberg" Position, blindfolded.

6. Romberg Position, left foot behind, eyes open. This is the traditional posture used in routine neurological examinations. The right heel is now placed in front of the left toe, and the plates are arranged accordingly, as shown on Figure 1 b.

FIGURE 1

MR and R POSITIONS OF FOOTPLATES



7. <u>Romberg Position, left foot behind, blindfolded.</u>

8. <u>Romberg Position, right foot behind, eyes open.</u>

9. <u>Romberg Position, right foot behind, blindfolded.</u>

Postures 8 and 9 are similar to postures 6 and 7, except that the rear-front position of left and right foot are switched. This switch in the Romberg posture was originally intended to explore effects of laterality. A similar switch is possible in the Modified Romberg, but was not included in order to keep the test short. The item "Standing on one foot with eyes closed" was also eliminated after it turned out to be stressful, difficult and unreliable.

These 10 items (Standing on one foot consists of two items, left and right foot respectively) require an administration time of 7 minutes approximately, including instruction and "warming up."

Henceforth the following abbreviations will be used throughout the text and tables for the various posture-items:

NO - Standing normally, eyes open
OF - Standing on one foot, eyes open (left and right foot combined).
NC - Standing normally blindfolded
MO - Modified Romberg, eyes open*
MC - Modified Romberg blindfolded
RO - Romberg, eyes open
RC - Romberg, blindfolded

Method of scoring and evaluation

The ataxiametric record as obtained by means of a four channel polygraph, consists of four curves, each depicting the weight displacement fluctuations registered by the two heel and two toe plates respectively. When the Subject stands without arm support the sum of the four deflections read across the four graphs at every time point equals the total body weight. Averaging the ordinates within a certain time span for the output of a single plate or group of plates yields the average percentage of body weight placed on that part of the ataxiameter.

The graphs lend themselves to traditional methods of wave analysis and there are many ways to classify and measure these ataxiametric wave patterns. However, it was beyond the scope of this Pilot study to explore the wealth of information provided by the ataxiametric output, chiefly because at this stage of research the graphs had to be analyzed by eye and hand. Methods of computer analysis, which will be employed in the future, require, besides

*Unless specially marked, all the M and R positions refer to rear placement of the left foot, for reasons which will be explained later.

expensive instrumentation, a well established rationale and system of scoring, which at the beginning had to be found by visual inspection of the graphometric data. The scoring method exmployed in this study is therefore only tentative and fragmentary. It may be still far from an optimal and most effective way of ataxiametric data evaluation and processing, which hopefully will be found by the aid of computer analysis.

Pretesting and preliminary experimentation has shown, that whilst the feet are in the MO, MC, RO and RC position, the burden of weight and balancing activity is borne by the rear foot. Therefore the analysis of rear foot patterns of these postures provides a score which is largely representative of the whole item. In a similar way, it was found out that whilst standing normally, the weight rests predominantly on the heels, so that again, heel fluctuation scores can be considered to be indicators of the whole performance. It should be noted that in both cases, the remaining ataxiametric recordings (namely those of the foot placed in front during the MO, MC, RO and RC postures and those of the toes whilst standing normally) - are complementary to the already scored parts of the item, as the sum of deflections in the four channels is constant and equals total body weight. Consequently it is also sufficient to score the heel (or toe) fluctuations of the "Standing-on-one-foot" postures. In this case the patterns of the second channel (the third and fourth being silent) are the exact mirror image of those produced by the first.

The presently used scoring method is thus as follows:

OF position: The distances between the peaks and bottom points within each of the first 15 second intervals of the heel waves of the left and right foot respectively are measured and summed. (The last 5 seconds of the performance were not evaluated, as standardized motor tests have shown that 15 seconds is a normal upper limit beyond which most children of the investigated age groups fail to keep balance). The score is defined as "Amplitude Score."

NO and NC position: To evaluate these items, the points of intersection of the wave with ordinates placed at one second intervals are assessed and the distances between these points and the base line are calculated for the 20 second performances of the left and right heels. The sum of discrepancies between successive pairs of adjacent distances yields the so-called "Fluctuation Score." In addition, the two distances created by both heels in synchrony at each of the 20 ordinates are added, resulting in 20 part sums. Again, the discrepancies between adjacent part sums are calculated and their sum yields the "Synchrony Score." This score indicates, how well the Subject, whilst standing normally, is able to balance on his heels and how much he uses forward-backward sway as additional control. An individual who would be able to keep his equilibrium by heel balance alone would have a Synchrony Score of zero. Finally, Fluctuation and Synchrony Score can be added to a single score, to be used as indicator of static balance activity during this posture.

In a similar way, Fluctuation and Synchrony Score are computed for the MO, MC, RO and RC positions. However, in this case, instead of using the two recordings of the left and right heel, the two recordings of heel and toe of the foot placed at the rear are analyzed. Consequently, the Synchrony score of this posture measures the amount of forward sway between the two feet placed one in front of the other. For RO and RC only the first 15 seconds are evaluated, for the same reasons as for the OF position.*

As the deflections produced by the electronic ataxiameter are actually measurements of weight, they must be divided by the total weight of the body, as otherwise scores of individuals of varying weight (and of course age) would not be comparable. All Amplitude, Synchrony and Fluctuation Scores, presented in this report are thus operationally defined as percentage scores, indicating the percentages of body weight displacements in relation to total weight. This purely operational value of the score should not be confounded with the impact of body weight on balance control, a problem which will be discussed in the following section.

As already mentioned before, it is possible to measure the average percentage of body weight placed on a certain part of the foot-plate set. In the context of this investigation, it was decided to assess the percentage of weight borne by the rear foot in the MO, MC, RO and RC positions. The calculation is as follows: The 40 (or 30) distance units already calculated for the measurement of Fluctuation and Synchrony Scores, are added and divided by the total weight, times number of distance units. This score will be referred to as "Weight Displacement Score."

Not all the theoretically possible scores were elaborated for the purpose of the present study, chiefly because of economy of time required for eye reading of the graphs. Furthermore, it seemed futile to use scores which showed a low test re-test reliability. The actual scores which have been computed for the whole sample of this study are the following:

OF - Sum of the two Amplitude Scores for left and right foot
NC - Sum of Fluctuation and Synchrony Scores
MO - Left foot in rear position - Weight Displacement Score
MC - Left foot in rear position - Weight Displacement Score
RO - Left foot in rear position - Sum of Fluctuation** and Synchrony Scores
RC - Left foot in rear position - Sum of Fluctuation and Synchrony Scores.

* Touching the floor or the handles results in large deflections which naturally cause the amplitude, synchrony and fluctuation scores to increase. It seemed therefore not necessary to score these "failures" by an additional scoring procedure.
** The Fluctuation Score of the RO and RC postures was computed only for the heels, as the toe fluctuations turned out to add no essential information.

It will be noted that no postures with the right foot in rear position were evaluated. This is due to the fact that these postures have low test-retest reliabilities, in contrast to the postures with the left foot placed behind the right. We assume that this discrepancy is an effect of laterality: in right handed subjects, who are the majority of the population, the preferred activity of the right hand, whilst standing, requires counter-balancing activity of the left foot. On the other hand, during the M. and R positions, the rear foot bears the burden of equilibrium control. It seems therefore plausible, that the left foot, better trained to counterbalance, will produce more reliable postural balance when placed at the rear.

Methodological considerations pertinent to the use of ataxiametric scores as experimental variables.

According to physical law the human body in upright, standing posture is in a so-called "not stable equilibrium," because the center of gravity is located above the area of support and thus tends to move downwards, i.e. the body would fall if the force of gravity would not be counteracted by muscle activity, which in turn is controlled by the neuro-physiological function of "static balance ability." In this context it should be noted that it is much safer to fall forwards than backwards, chiefly because the arms can be used as shock absorbers. Therefore when equilibrium is threatened, the body tends to lean forward.

The amount of "stability" of a physical body similar in form and position to a standing human subject is positively related to its weight and to the area of the support, as well as negatively related to the vertical distance of the center of gravity from the base.

Thus, if the forces of neurophysiological balance control would remain constant in the growing child, his physical stability would increase by virtue of weight increment and growth of the plantar surface. On the other hand, increasing height would lower the degree of his stability. In addition to these three factors, the physical structure of the growing body changes its dimensions and proportions which must be taken into account when an attempt would be made to calculate the developmental changes in the interaction of the purely physical vectors determining body equilibrium. Obviously, an imaginary magic doll which would grow in its body proportions like a child, whilst being kept in standing posture by an unchanging mechanism of equilibrium control, would not maintain its upright position. This means that in children, static balance ability is a function which has to adapt continuously to the changing mass and proportions of the growing body, a process which in itself would be worth to be investigated. This also implies that static balance ability is foremost a dependent variable, in that height and weight, and a host of unknown factors determine the amount and range of physical forces to be counteracted by neurophysiological equilibrium control.

However, in the frame of reference of the present project, static balance ability is treated as an independent variable, the dependent variables being the cognitive processes involved in school readiness. Ideally, if the laws of the intrinsic relationship between static balance and body growth would be known, we would probably possess a formula which would statistically control the impact of body growth on the former, so that the cognitive variables could be correlated with "uncontaminated static balance ability." However, research as far as we are informed at this moment, has not yet produced such developmental data.*

On the other hand it must be kept in mind that cognitive variables on their part might be correlated with weight and height, although according to literature, these correlations tend to be positive, low and insignificant. (Abernethy, 1936; Jones, 1939; Jones, 1965).

Finally consideration must be given to the fact that our ataxiametric scores are percentages of weight, so that a heavy child might have a low ataxiametric score (indicating high stability) by virtue of his weight, which by physical law renders his posture more stable and which in addition, functions as a denominator in his score. This circumstance would be suspect to cause spurious correlations of stability with weight, in a way intelligence quotients tend to correlate spuriously with chronological age, because the latter is the denominator of the IQ. However, the effects of such a spurious correlation between weight and ataxiametric scores are limited by the following factors:

a. The numerator of the ataxiametric score (i.e. the seize of deflections) is directly proportional to weight by virtue of the design of the apparatus, which is basically a type of electronic scales. This counterbalances the function of weight in the denominator, and is supposed to cancel it out. This interdependence is fundamentally different from the nature of the IQ, where mental age (the nominator) is not a direct function of chronological age (the denominator), although it correlates with the former.

b. Weight is substantially correlated with height in the growing child, but the latter has a negative effect on stability and would thus tend to counterbalance the increase of stability gained through greater weight.

*Physical medicine has investigated the position of the center of gravity, the distribution of forces at the main joints, involved in standing, i.e. ankle, knee, hip and neck, etc. These studies however have been carried out on adults and are not focused on individual differences and developmental patterns. (For an exhaustive bibliography on this subject see Akerblom (1948), Joseph (1960), Leger (1959) and Smith (1957).)

In the light of all these considerations, it is obvious that any methodological use of ataxiametric scores as experimental variables must include a statistical control of weight and height.* For all practical purposes of the present study this control may be achieved by the traditional method of partial correlation. Hopefully further research will lead to an elaboration of ataxiametric scores which would include coefficients of correction, reflecting the factual interaction of physical and physiological forces operating during the maintenance of equilibrium.

As to the extrinsic intercorrelations between ataxiametric scores, mental tests and weight and height respectively, (which have been calculated in this study for the sake of eliminating the effect of the latter) - their mutual direction can by no means be predicted and may show considerable variation. Partialling out weight and height must not necessarily lower the correlations between ataxiametric and mental scores. They may eventually increase, especially when height is eliminated, which tends to correlate positively with cognition and negatively with stability. On the other hand, partialling out of weight, supposedly related positively to both, cognition and stability, would be expected to cause a decrease of the correlation between ataxiametric and mental scores. Of course, the combined control of weight and height might be mutually counterbalancing, so that their elimination might have only a little final effect on the relationship between cognition and static balance ability as measured by the ataxiameter.

* The additional intervening effect of plantar surface is supposed to be minimal, in light of its high correlation wieh height, once the latter has been controlled. Besides, its effect is minimized by virtue of the insensitivity of the plates to horizontal weight shifts within the individual plate area.

MEASURES OF CRITERION VARIABLES

The main purpose of this study being the exploration of the relationship between static balance ability and school readiness, the criterion measures are supposed to be indicative of basic scholastic achievements in three main functional areas, namely, perceptual differentiation, language development and reading, and elementary manipulation of number concepts. In addition it seemed to be desirable to evaluate the pupil's social "school readiness," specially at the Kindergarten level. Accordingly, the following instruments were selected to measure the criterion variables which were assumed to be related to the ataxiametric scores:

a. Kindergarten. Bender Gestalt Test (Perceptual), Peabody Picture Vocabulary (Language), Arithmetic School Readiness Test (Numerical), and Teacher Observation Inventory (Social).

b. First Grade. Metropolitan Readiness Test (1965 edition)* and Stanford Achievement Test (1965 edition)**. The former is composed of perceptual, numerical as well as of verbal subtests, whereas form of the Stanford Achievement Test which was used measures reading ability (Form W).

c. Second Grade. Stanford Achievement Test second grade level.

These instruments were administered to the main sample of the Pilot Study. The sample of a smaller Pretest project, consisting of first, second and third graders, were given the Bond-Balow-Hoyt New Developmental Reading Tests *** containing mainly reading items.

The predictive and construct validity of the Bender, Peabody, Stanford and Bond-Balow-Hoyt tests have been well established in various studies. They are significantly related to scholastic achievement as well as to general Intelligence Tests, such as the Binet-Simon and WISC. The Arithmetic Readiness Test has been recently constructed by Dr. Abraham Minkovitch of the Hebrew University,**** Jerusalem and has been validated on Israeli populations. This test which is given at school entrance age has been shown to predict scholastic achievement at the end of the first and second grades. The Kindergarten Teacher Observation Inventory, designed by Mrs. Zipporeth Kohen-Raz is since three years in routine use at the Municipal School Guidance Clinic of Jerusalem. Its inter-judge reliability and concurrent validity in relation to Binet-Simon items for ages 5 to 6 have been demonstrated. Results of an ongoing longitudinal follow up to explore its predictive validity are not yet available.

* Published by Harcourt, Brace & World Inc. New York
** Published by Harcourt, Brace & World Inc. New York
*** Published by Lyons and Carnahan, Chicago
**** Published by the Ministry of Education, Jerusalem, 1967.

The Peabody Picture Vocabulary and Bender Gestalt Test are well known and do not warrant any further description. The Metropolitan Readiness Test has 6 parts. The "Word Meaning" part is essentially a picture vocabulary. The "Listening" items are supposed to measure the ability to grasp the meaning of vocally presented sentences, some of them describing actions. In the "Matching" test the Subject is asked to match a geometrical figure, characterized by a rather unobtrusive detail, with an identical counterpart hidden among distractors. The Numerical part confronts the examinee with simple numerical and arithmetic problems whereas the "Copy" test requires to produce visually presented letters, forms and figures.

The form of the Stanford Achievement Test which was used has four subtests and a Total Reading Score. The first part is again a picture vocabulary, the second tests the reading and understanding of visually presented printed paragraphs, part three examines the understanding of a vocally presented vocabulary, whereas part four requires auditory perception and discrimination of beginning and ending sounds, phonics and phonograms.

The Bond-Balow-Hoyt Reading Test is composed of three parts. Part one is a picture vocabulary, part two examines the understanding of meaningful passages and part three measures discrimination of a concept, as well as general comprehension of situations.

The Arithmetic Readiness Test has six parts.

a. Counting. The child has to count various objects and is asked which number comes before or after a certain digit.

b. Number Groups and Fractions. The child is required to tell the number of circles in a group without counting them and to demonstrate the knowledge of the concepts "half" and "a quarter."

c. Ordinal Numbers. This test examines the ability to define correctly the first, last, middle, fourth, fifth, smallest, biggest, etc. item in a series of visually presented objects.

d. Coordination. A certain number of paper circles, representing "balls" has to be matched with a smaller number of depicted "children," supposed "to play each with one ball only."

e. Conservation of Numbers. This is a Piagetian type of problem, testing the concept of number conservation in front of distracting visual presentations of a constant number of objects.

f. Arithmetic Problems are presented, requiring the addition and subtraction of coins within the limits of one to five.

The Kindergarten Teacher Observation Inventory consists of 19 items. (See appendix). The following parts of it were scored and used as criterion variables. a. Physical characteristics (Item 3), b. Level and quality of activities (Item 11), c. Story reproduction (Item 13), d. Social relationship (Item 17), e. Overall evaluation of school readiness, based on the preceding items (Item 19). The inventory was filled out by one of the research assistants, who interviewed the Kindergarten Teacher on each child.

SAMPLE

As already mentioned, this investigation is based on two samples: The Pre-Test Sample, Sample "A," and the Pilot Study Main Sample, Sample "B." The Pre-Test Sample is composed of 66 Ss from grades I, II and III of one Palo Alto Elementary School, which will be referred to as School I. The population of the Main Sample was recruited from two Schools of the Redwood City School District (referred to as Schools II and III) and consisted of 140 Ss. (Breakdown according to sex and grade is given on Table 1). In addition, 33 pupils at ages 9 to 10, who have been placed in special classes for Educationally Handicapped (not mentally retarded) were tested with the ataxiameter. 12 of these belonged to a special class in Palo Alto and 21 came from three different classes of the Redwood City School District. Most Ss of the normal population, as well as those from the special classes were Caucasian white (Anglo-American and Spanish Mexicans), and a small minority were Orientals. No Black Ss were included according to the original design of the study in order to control eventual racial differences of psychomotor development.

Parental consent to let their children participate had to be obtained, the number of non consenting parents however was negligible. Due to illness and absence on the days group tests were given the number of records eligible for final elaboration was smaller than the originally recruited sample, comprising one class at each grade in Sample A and two or three classes at each grade in Sample B.

TABLE 1

SAMPLE

	(A)		(B)		
Grade	Boys	Girls	Boys	Girls	Total
K	-	-	26	25	51
I	16	11	24	23	74
II	9	9	20	22	60
III	12	9	-	-	21
Total	37	29	70	70	206

PROCEDURE

Sample A was examined in January 1969 with the ataxiametric battery, which included items NO, NC, OF, MO, RO and RC (the latter only with the left foot in rear position), as well as standing on one foot with eyes closed. Independently from these examinations, the whole sample was group-tested with the Bond-Balow-Hoyt New Developmental Reading Tests in the context of routine examinations given to the whole School District. (Grades two and three were tested in October 1968 and grade one in April 1969).

The testing of Sample B took place in April-May 1969. The principal investigator and one research assistant carried out the individual ataxiametric examinations. The same research assistant also administered individually the Peabody Picture Vocabulary to the Kindergarten populations. At the same time a second research assistant interviewed the Kindergarten Teachers and filled out the Teacher Observation Inventory on each Kindergarten child. The second assistant also gave the Bender Gestalt and Arithmetic Readiness Test in individual sessions. Hereafter the first graders were given the Metropolitan Readiness Test in group form. The Stanford Achievement Tests had been already administered to grades one and two in March 1969 by the School District Testing Services as a routine evaluation of the district school population.

In the ataxiametric battery given to sample B, the one-foot-eyes-closed items were omitted and instead MC, left foot in rear position and RO and RC, right foot in rear position, were added.

The Bender, Peabody, Arithmetic Readiness, Teacher Observation and Metropolitan data were elaborated first and only afterwards the ataxiametric records were analyzed and scored. The scores of the Stanford Achievement tests were supplied by the School District Authorities in July 1969, after all the other results were already recorded.

Test-retest reliability of the ataxiametric method was assessed by re-examining 26 first graders four days after their first ataxiametric examination. Seven of these were from Sample A and 19 from Sample B.

RESULTS

The tabulated ataxiametric scores have been computed as detailed above (page 13). This means that OF is an Amplitude Score, and NC, RO and RC are combined Fluctuation and Synchrony Scores. As large deflections, fluctuations and synchrony-discrepancies must be considered as a sign of weak balance ability, the assumed positive relation between stability and cognition will be expected to show up in negative correlations between OF, NC, RO, and RF respectively and mental scores. On the other hand, MO and MC are Weight Displacement Scores, a high score indicating that weight is predominantly shifted backwards. As already mentioned (above, page 14), an insecure and unstable standing posture is characterized by leaning forward, probably in order to prevent the rather dangerous backward fall. Consequently high MO and MC scores are supposed to be a sign of good stability and therefore the direction of their correlations with mental scores is expected to be positive.

Data have been presented in such a way as to allow to inspect conveniently the effect of the major intervening variables, namely sex, weight and height.

Reliability

Table 2 shows that the ataxiametric items have quite different degrees of reliability. The reliability of MO (.81), MC (.71) and the composite score MO + OF (.88) would satisfy the requirements of any mental or behavioral test many times longer than these micro-units of 20, 30 and 50 seconds. The reliabilities of OF (.67), NC (.64), (L)RC(.51) and (L)RO (.42) were considered to be acceptable in the context of this exploratory study, taking also into account the still imperfect and tentative method of scoring based on eye-hand elaboration of the record.* On the other hand the reliability of NO, (R)RO and (R)RC -- i.e. normal standing with eyes open and Rombergs with the right foot in rear position -- turned out to be so low, that their elimination from the battery seems to be justified, although the reason of their unreliability which contrasts with a considerably higher reliability of very similar items, seems to be worth further investigation.

* It is theoretically possible to compute split-half reliabilities of the ataxiametric items which would lead to the comparison of test units smaller than 16 seconds. Even if such small units would show a high split-half reliability it would not be too meaningful, because it could be argued that in such a small time span a response is stable by virtue of its organismic unity, without being reliable in the sense of replicability. On the other hand, absence of split-half reliability would again be inconclusive, as we might pick up

* The seize of these reliability coefficients if not very different from those obtained with crude measures of static balance performance on longer items. (Keogh, 1965, 1968).

TABLE 2

TEST RETEST RELIABILITY OF ATAXIAMETRIC SCORES

	Duration of Posture in Sec.	a	b
NO	20	.33	.50
OF	30	.67	.80
NC	20	.64	.78
MO	20	.81	.90
MC	20	.71	.83
*(L)RO	15	.42	.59
(L)RC	15	.51	.68
(R)RC	15	.11	.20
MO + OF	50	.88	.94

(a) Pearson r between test - retest.

(b) Estimate of reliability of item of twice as long a duration as computed by Spearman-Brown formula.

* Letters L and R in parenthesis refer to left/right foot placed in rear position.

two complementary, but differently patterned phases of an integrated response, which as a whole could be replicable and reliable.

In any case the burden of proof of reliability remains on the computations of test-retest correlations.

Developmental patterns and sex differences

Table 3 and Figure 2 shows that the Amplitude, Fluctuation and Synchrony Scores of OF, NC, RO and RC * show a definite progress by age, which is steeper and more consistent in girls than in boys. Furthermore, girls are consistently superior in their static balance ability on these four items, although the difference is significant only in four instances.** It will also be noted that sex differences conspicuously increase after school entrance (from grade one onward).

On the other hand, MO and MC do not show any clear developmental pattern and also no consistent sex differences. The third grade sample is too small to justify the assumption of an eventual curvilinear development in girls. There seems to be a divergence in the development of MO and MC in boys. MO tends to decrease, where MC increases.

It should be noted that the direction of sex differences as an indirect proof that there is no spurious relationship between the ataxiametric scores and weight, liable to be caused by the latter's function as denominator of the former. (See above p.).

If such a spurious relationship would exist, the heavier boys should have lower ataxiametric scores (indicating higher stability) -- which evidently is not the case. On the other hand the precocity of girls supports the assumption that static balance ability is related to organismic maturation, which is known to be more advanced in girls.

The data on mental and scholastic achievements presented on Tables 4 a, b, c, d show no significant sex differences although boys tend to be insignificiently superior in numerical skills and girls in reading ability, a finding which has been repeatedly reported in many studies.

However, the existence of sex differences in similar direction on both, ataxiametric and mental scores, in spite of absence of significance, is liable to arise suspicion, that relationships found between balance ability and reading could be the result of a

* All MO, MC, RO and RC scores reported forthwith refer to postures with left foot in rear position.

** These findings are in accordance with all previous studies exploring sex differences in static balance ability.

TABLE 3

DEVELOPMENTAL PATTERNS OF STATIC BALANCE ABILITY

	Kindergarten				I Grade				II Grade				III Grade				Ed. Handicapped Age/Grade III			
	N = 26 Boys		N = 25 Girls		N = 24 Boys		N = 23 Girls		N = 20 Boys		N = 22 Girls		N = 12 Boys		N = 9 Girls		N = 28 Boys		N = 5 Girls	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
OF	57	20	56	29	51	28	38*	15	41	22	35	13	42	19	30	13	39	15	46	22
NC	36	11	36	12	31	10	30	7	29	12	29	11	33	9	26+	5	36	16	42	30
MO	76	9	72	9	74	12	73	12	72	19	76	11	66	12	70	9	74	14	65	10
MC	70	9	68	10	70	11	73	11	75	12	72	11	-	-	-	-	71	12	-	-
RO	28	11	29	16	25	11	24	9	25	12	21	8	-	-	-	-	-	-	-	-
RC	44	19	38	15	36	12	36	14	37	11	31*	10	31	10	26+	8	34	12	36	16

	N = 16 Boys		N = 11 Girls		N = 9 Boys		N = 9 Girls	
	M	SD	M	SD	M	SD	M	SD
OF	58	31	42*	16	46	15	46	15
NC	38	17	36	18	35	14	35	14
MO	66	9	75*	11	65	11	65	11
MC	-	-	-	-	-	-	-	-
RO	34	10	24*	9	-	-	-	-
RC	31	7	28	11	33	12	32	12

* Sex difference significant at .05 level

\+ Sex difference significant near .05 level

FIGURE 2

DEVELOPMENTAL PATTERNS OF ATAXIAMETRIC SCORES

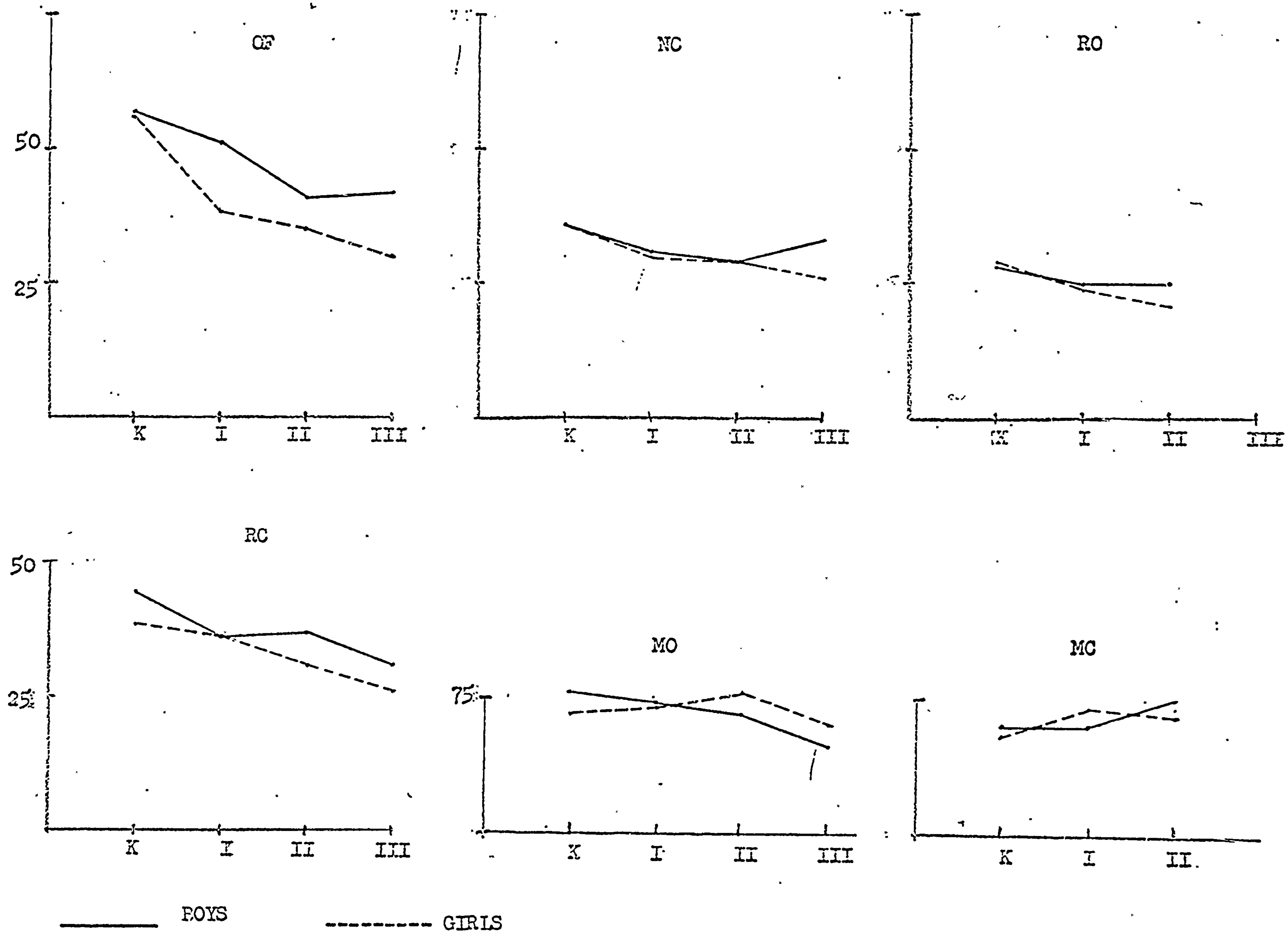


TABLE 4 a

MEANS AND STANDARD DEVIATIONS OF CRITERION VARIABLES

KINDERGARTEN

		Boys N = 26 M	Boys N = 26 SD	Girls N = 25 M	Girls N = 25 SD
Bender		100	9.1	97	2.1
Peabody		58	5.4	57	5.2
Teacher Evaluation		3.5	1.22	3.9	1.30
ARITHMETIC READINESS TEST	Count	15.4	3.66	15.8	3.19
	Groups & Frct.	5.1	1.35	4.7	1.49
	Ord. Numb.	9.4	3.37	9.4	3.12
	Coord.	5.2	2.59	4.6	2.55
	Conser.	4.0	2.38	3.9	2.47
	Arith. Probl.	5.8	2.67	4.8	2.65

TABLE 4.b

MEANS AND STANDARD DEVIATIONS OF CRITERION VARIABLES

GRADE I, SAMPLE B

Test	Variable	Boys (N = 24) M	Boys (N = 24) SD	Girls (N = 23) M	Girls (N = 23) SD
METROPOLITAN READINESS TEST	Word	11.9	1.58	10.5	2.61
	Listen	12.8	2.32	12.6	2.57
	Match	10.6	3.93	10.[illegible]	3.45
	Number	11.8	9.51	11.5	2.36
	Copy	10.8	2.84	10.4	3.26
STANFORD ACHIEVEMENT TEST	Word	20.3	7.57	21.5	6.75
	Parag. Mean.	17.9	10.31	22.0	8.30
	Total Read.	39.4	17.05	43.4	13.81
	Vocab.	20.8	7.15	19.0	5.16
	Word Study	36.2	9.3	37.5	12.4

TABLE 4 c

MEANS AND STANDARD DEVIATIONS OF CRITERION VARIABLES

GRADE II, SAMPLE B

		N = 20 Boys		N = 22 Girls	
		M	SD	M	SD
Stanford Achievement Test	Word Read	18.7	6.1	21.1	5.2
	Parag Mean	29.7	12.8	33.2	11.2
	Total	47.0	17.8	54.4	15.6
	Word Study	37.3	12.0	43.5	11.6

TABLE 4 d

MEANS AND STANDARD DEVIATIONS OF CRITERION VARIABLES

SAMPLE A

Total Scores of Bond-Balow-Hoyt New Developmental Reading Tests

	Boys			Girls		
Grade	N	M	SD	N	M	SD
I	16	167	32	11	174	35
II	9	26.6	7.3	9	30.5	6.0
III	12	44	6.0	9	46	1.2

coincidence of parallel sex differences in two functions which are not necessarily interdependent. (Such as a possible correlation between the length of hair and reading skill, caused by the fact that girls have longer hair and also read better).

On the other hand, if relationships between balance ability and mental variables can be demonstrated to exist in sex-combined groups as well as within the sexes, the fact that girls are motorically and mentally precocious then would support an organismic hypothesis, assuming that progress in balancing and cognition is functionally inter-related and eventually based on a common maturational process.

The data on the Educationally Handicapped, presented on Table 5 for convenient comparison, will be discussed later.

Correlations between ataxiametric scores and measures of school readiness and reading skills

Kindergarten

As shown on Table 5, OF correlates significantly with Teacher Evaluation of School Readiness,* as well as with two subtests of the Arithmetic School Readiness Test, namely "Group and Fractions" and "Arithmetic Problems." ** RC besides being also related to Teacher Evaluation, correlates with the Bender Gestalt. The correlation between a composite score OF + RC with Teacher Evaluation reaches the .01 level of significance.

When weight and height are partialled out the relation between RC and Bender vanishes, whereas the correlation coefficients with OF and the composite score OF + RC are not substantially affected, obviously because of their negligible correlations with height and weight.

When sexes are separated, the correlations between OF and arithmetic school readiness, as well as those between RC and Bender somewhat decrease in size in the male sample, but remain constant or slightly increase in the group of girls. However, none of these coefficients is significant, chiefly due to the shrinkage of N. In addition, elimination of weight and height again depresses the relation between RC and Bender. (Table 5b).

* The Kindergarten population has been sampled from three classes (two from School II and one from School III), each having been evaluated by its own teacher. The Teacher evaluation ratings thus originate from three different teachers.

** The correlations between these subtests and the Total Arithmetic Readiness Score which in Israel has been shown to predict scholastic success, are as follows: Group and Fractions: .71; Arithmetic Problems .81.

TABLE 5 a

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND MEASURES OF SCHOOL READINESS

KINDERGARTEN, BOTH SEXES

N = 51

	a)			ARITH. SCHOOL READINESS						b)	
Mental Atax	Bender	Pea-body	Teach Eval.	Count	Group & Frct	Ord Numb	Co-ord	Con Serv	Arith Probl	Weight	Height
OF	-18	-07	-26*	-20	-29*	-22	02	-08	-30*	01	03
NC	-08	22	12	23	19	19	24	21	17	13	22
MO	-13	-01	-07	-13	00	01	-05	00	06	-04	22
MC	05	05	14	-03	-10	01	04	21	06	-05	15
RO	-18	-19	01	-08	-16	02	-06	-01	02	-06	-18
RC	-28*	-01	-33*	-24	-08	-14	04	01	03	03	-29
OF + RC			-36**							-08	-10
Weight	-13	18	21	19	10	24	-02	13	17		87
Height	07	15	38	46	15	40	07	23	26	87	

* P = .05 ** P = .01

(continued)

TABLE 5 a (continued)

a) All correlation coefficients are Pearson r except for Teacher Evaluation, where Spearman rho was computed. Teacher Evaluation variable is item 19 of the Teacher Observation Inventory and consists in a 5 point rating scale of school readiness: not ready, marginal, moderately ready, essentially and definitively ready.

b) Not for all subjects tabulated on Tables 5, 6 and 7 height measures were available. In light of the general valid and high correlation between height and weight (the measures for the latter being available for the whole sample) the height correlations in the part of the sample were considered as representative of the whole sample and used for the computation of partial correlations. The significance levels however of the height correlation and partial correlation coefficients were not defined.

TABLE 5 b

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND MEASURES OF SCHOOL READINESS

KINDERGARTEN, SEXES SEPARATED

Boys N = 26
Girls N = 25

	Bender		Teacher Evaluation		Groups & Fract.		Arith. Probl.	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
OF			-11	-43*	-22	-34	-25	-29
RC	-20	-35	-27	-37*				
OF + RC			-17	-52**				

A striking sex difference shows up in the relationship between OF, RC, OF+RC and between Teacher Evaluation. In spite of shrinkage of N and restriction of range (as shown on Tables 3 and 4, girls are evaluated higher on school readiness and are also precocious in their ataxiametric performance) -- the correlations within the female sample remain significant, but drop substantially in boys.

As mentioned before, the Teacher Evaluation scores are pooled from three different classes and teachers. It was therefore of interest to explore the interaction between teachers, sexes, ataxiametric scores and evaluation of school readiness. A~ only 3 boys and 2 girls came from the second of the two classes in School II the scores of School II were treated as if originating from one teacher only, so that the two schools and not the three teachers were compared. It turned out, that the teachers of School III gave higher evaluation scores to both sexes, but only in the case of girls this difference was significant. Within School II, the two teachers evaluated more children than in School III as "moderately or low" on school readiness and the correlation between Teacher Evaluation and OF+RC is -.76 (N=12) for girls and -.08 (N=15) for boys. Within School III the same data are -.22 (N=12) for girls and -.17 (N=15) for boys. This discrepancy between the two schools in the correlation coefficients within the female sample is probably a result of restriction of range as 10 out of the 12 girls of School III were evaluated as well or definitively ready for schools, and only one girl as moderately ready and one girl as not ready.

It will be noted on Table 5 that height and weight tends to correlate substantially (although not significantly) with school readiness criteria (especially with teacher evaluation) in positive direction. This seems to indicate that the well known "school entrance growth spurt" may be accompanied by a parallel "mental growth spurt." From the point of view of ataxiametric measurement of school readiness, this growth sput is liable to "depress" the relationship between static balance ability and mental scores, if the former is negatively correlated with weight and/or height, as it is the case with RC. On the other hand, when the ataxiametric scores are unrelated to height and weight (as it is the case with OC and OC+RC), physical growth measures and static balance scores may provide the basis for a multi-correlational prediction of "organismic school readiness" of promising validity.

It may be argued that among so many insignificant correlations presented on Table 5, the relationship between ataxiametric scores and Arithmetic Readiness and Teacher Evaluation respectively could be due to chance. Although this possibility cannot be entirely negated until cross validation data on a similar sample will be available, it seems that there are some limitations to pure chance effects:

a) Table 5 is not a confrontation of 6 x 9 independent variables, but actually tabulates the relationship between one static balance ability test (composed of 6 items) and four school readiness measures, the arithmetic readiness instrument having 6 intercorrelated parts. As the aim of the study is explorative, it was important to inspect all the possible 54 inter-item relations, instead of 4 inter-test correlations.

b) As will be demonstrated later, OF correlates consistently with cognitive variables in 5 independent age/grade subsamples of this study. This would weaken the assumption, that its correlations with two criterion variables in the Kindergarten population are due to chance.

First Grade

In the first grade of Sample A the Total Score of the Bond-Balow-Hoyt Reading Test (Lower Primary Level), used as a single criterion variable, correlates significantly with the composite score OF + MO. (Table 6). This relationship is not affected by elimination of weight and height and reappears within each sex group, naturally reduced by range restriction and shrinkage of N.

In the larger first grade population of Sample B these results are cross-validated in that OF and MO (this time each item by itself) correlate significantly with the Paragraph Meaning subtest and the Total Score of the Stanford Achievement Test. (Primary I Level). Combining OF and MO and adding RO, the resulting composite score OF + MO + RO correlates with reading at the .002 level. (Table 7a). Partialling out of height and weight tends to increase these correlation coefficients (Table 7b). When sexes are separated the combined OF-MO-RO score continues to be significantly related to Word Reading, Paragraph Meaning and Total Score in both sexes, the relationship being more pronounced in girls.

MO seems to be a good single predictor of Stanford Word Reading, Paragraph Meaning and Total Reading Score in the sex-combined as well as in the female sample, whereas in boys MO correlates only with the Stanford Word Study subtest. (See Tables 7a, 7c and 7d).

RO seems to be sensitive to sex differences in the relationships between ataxiametric scores and school readiness tests: Its correlations with the Match and Number parts of the Metropolitan Readiness Test, which are marginally significant when sexes are combined (Table 7a), turn out to be sex specific, in that a significant correlation with the Number subtest shows up only in the female sample and one with the Match subtest appears exclusively in boys. Another sex difference emerges in the relationship of RO with the Metropolitan Word and Stanford Vocabulary subtests, the relationship with both tests being conspicuous in girls and absent in boys. On the other hand, in the male sample there is a somewhat higher correlation between RO and Stanford Word Reading.

TABLE 6

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND BOND-BALOW-HOYT READING TEST

GRADE I, SAMPLE A

BOTH SEXES
N = 26

	Reading Score	Weight	Height	Reading W&H Elimin.
OF	-29	-33	-10	-34
NC	-36	-19	-21	-44*
MO	31	-58*	-14	32
RO	-11	-23	-09	
RC	-15	-16	-16	
OF+MO	-38*	-08	96	-40*
Weight	-07		51	
Height	03	51		

BOYS
N = 16

	Reading Score	Weight	Height	Reading W&H Elimin.
OF	-30	-48	-10	-34
NC	-32	-21	10	-37
MO	20	-43	-07	24
RO	-12	-36	-14	
RC	-23	-33	-14	
OF+MO	-41	-34	07	-50*
Weight	10		58	
Height	15	58		

GIRLS
N = 11

	Reading Score	Weight	Height	Reading W&H Elimin.
OF	-15	-37	-46	-31
NC	-37	-18	26	-55
MO	26	-68	08	-04
RO	25	-46	-37	
RC	-09	-04	13	
OF+MO	-29	08	-45	-27
Weight	-36		39	
Height	-05	39		

TABLE 7 a

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES, METROPOLITAN READINESS TEST AND STANFORD ACHIEVEMENT TEST

GRADE I, SAMPLE B, BOTH SEXES

N = 47

	Word	Listen	Match	Number	Copy	Word Read.	Para. Mean.	Total Read.	Vocab.	Word Study	Weight	Height
OF	16	-08	-09	-08	-09	-24	-33*	-37**	-04	-05	-10	27
NC	10	07	12	06	-05	-20	-07	-08	-08	-07	-26	11
MO	-05	07	15	22	05	43**	35*	30*	15	17	-26	-21
MC	01	05	07	-06	-20	15	08	-12	01	-02	-18	12
RO	-21	13	-28+	-26+	-01	-31*	-19	-26	11	03	-13	-18
RC	-17	05	-30*	04	15	06	01	03	19	-04	-11	38
OF+MO+RO						-44**	-44**	-47***			-01	24
Weight	-06	29*	03	11	-06	13	11	10	13	00		72
Height	18	03	-20	-28	06	24	15	00	23	-12	72	

+ P approaches .05 * P = .05 ** P = .01 *** P = .002

TABLE 7 b

SIGNIFICANT CORRELATIONS OF TABLE 7 a AFTER HEIGHT AND WEIGHT HAS BEEN PARTIALLED OUT

	Match	Numb	Word Read	Para Mean	Total Read
OF				-43	-36
MO			50	40	34
OF+MO+RO			-57	-51	-47
RO	-34	-37			
RC	-12				

TABLE 7 c

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES, METROPOLITAN READINESS TEST AND STANFORD ACHIEVEMENT TEST

GRADE I, SAMPLE B, BOYS

N = 24

	METROPOLITAN READINESS TEST					STANFORD ACHIEVEMENT						
	Word	Listen	Match	Number	Copy	Word Read	Para Mean	Total Read	Vocab	Word Study	Weight	Height
OF	-30	-34	-16	02	-34	-04	-23	-23	02	06	-36	34
NC	03	-23	03	02	-18	10	-02	03	-01	00	-15	35
MO	16	-08	-01	01	-36	12	22	31	16	40*	-23	-27
MC	01	-03	-01	11	-38+	-12	-06	01	05	18	-41*	-44
RO	00	14	-43*	-20	16	-44*	-15	-22	02	-04	-23	-06
RC	-32	12	-35	00	-08	14	-01	06	-09	12	-12	45
OF+MO+RO						-46*	-37+	-42*			-10	-09
Weight	18	10	07	13	-13	30	33	32	41*	07		65
Height	33	-53	01	-28	-23	42	30	41	-05	07	65	

TABLE 7 d

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES, METROPOLITAN READINESS TEST AND STANFORD ACHIEVEMENT TEST

GRADE I, SAMPLE B, GIRLS

N = 23

	METROPOLITAN READINESS TEST					STANFORD ACHIEVEMENT						
	Word	Listen	Match	Number	Copy	Word Read.	Para. Mean.	Total Read.	Vocab.	Word Study	Weight	Height
OF	-17	-09	13	-15	-17	-21	-29	-28	-04	-27	04	-13
NC	11	-19	16	06	12	-29	-11	-21	-23	-18	-19	-70
MO	-25	38	23	36+	42*	56**	59**	63**	-06	32	-28	-33
MC	07	-06	20	19	-02	17	22	22	02	-01	-07	63
RO	-41*	-13	-16	-42*	-05	-31	-26	-34	-44*	-33	-10	23
RC	-04	16	-07	03	40*	-05	06	03	37	13	-12	31
OF+MO+RO						-50*	-58**	-59**			14	06
Weight	11	20	-03	10	03	03	-15	-05	20	-02		55
Height	09	59	-44	-30	18	-28	-15	-15	15	-47	55	

TABLE 7 e

SIGNIFICANT CORRELATIONS OF TABLES . c AND 7 d.
AFTER HEIGHT AND WEIGHT HAVE BEEN
PARTIALLED OUT

BOYS

	Match	Word Read	Para. Mean	Total Read	Word Study
OF					
MO					44
MC					
RO	-42	-46			
RC					
OF + MO + RO		-47	-36	-42	

GIRLS

	Word	Number	Copy	Word Read	Para Mean	Total Read	Vocab.
OF				-30	-31	-31	
NC							
MO		35	51	51	57	63	
RO	-44	-31					-48
RC			36				
OF + MO + RO				-55	-57	-60	

RC is correlated with the perceptual Match subtest, a relationship which reminds that of RC with the visual-motor Bender Gestalt Test at the Kindergarten level. However this relationship is apparent only in boys. Besides, it is again reduced to insignificant size, when height and weight are controlled. (Table 7b).

In girls only, RC correlates also with the Metropolitan Copy subtest, but in inverse direction, i.e. higher fluctuation being related to higher mental scores. However this Copy test correlates in expected direction (i.e. lower fluctuation indicating higher mental scores) with MO, again only in the female sample, whereas the correlation between MO and Copy is zero, when the sexes are combined. These inconsistencies seem to indicate that the relationships between static balance ability and "perceptual school readiness" are either unstable and unreliable or inadequately measured by our present scoring system.

All the before-mentioned correlations, with the exception of that between RC and Match, and RO with Number in girls, are not essentially affected by the elimination of weight and height. (Tables 7b and 7e).

It should be noted that at the first grades OF does not correlate with perceptual and nume rical (i.e. NON-verbal) school readiness tests. It is furthermore of interest that the more complex reading skill, as measured by Paragraph Reading, correlates substantially and consistently with ataxiametric scores, whereas those items of the Stanford Achievement Test which measure predominantly auditory discrimination and the understanding of vocally presented words, show generally low and only sporadically significant correlations.

Second Grade

At the second grade of Sample A, OF as a single item correlates significantly with the Total Score of the Bond-Balow-Hoyt Reading Test (Upper Primary Level), used again as the only criterion variable. The relationships between MO and reading, which were found at the first grades, disappear. On the other hand, NC and RC, although not significantly related as single items, combine together with OF into a composite score of considerable validity, manifest in a correlation coefficient of -.54, after weight and height has been eliminated. The relationship between static balance ability and reading skill in this sample is not affected neither by height or weight nor by sex differences. (See Table 8).

Grade II of Sample B shows a single significant correlation between the composite score OF + RO and Paragraph Reading of the Stanford Achievement Test (Primary II Level). This relationship although not dependent on height and weight, is considerably reduced within the sex groups, and could easily be dismissed as being the product of chance, were it not consistent with findings in

TABLE 8

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND BAND-BALOW-HOYT READING TEST

GRADE II, SAMPLE A

	BOTH SEXES N = 18				BOYS N = 9			
	Reading Score	Weight	Height	Reading W&H Elimin.	Reading Score	Weight	Height	Reading W&H Elimin.
OF	-48*	-03	14		-51	-41	-47	
NC	-39	-30	12		-44	-52	-22	
MO	08	-09	04		19	11	26	
RC	-41	-20	28		-43	-31	-36	
OF+NC +RC	-50*	-24	-22	-54*	-53	-63	-55	-53
Weight	02		84		21		88	
Height	-13	84			14	88		

GIRLS
N = 9

	Reading Score	Weight	Height	Reading W&H Elimin.
OF	-27	05	-18	
NC	-45	-03	08	
MO	-46	24	27	
RC	-41	04	-20	
OF+NC+RC	-50	37	-31	-61
Weight	00		18	
Height	-04	18		

TABLE 9 a

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND STANFORD ACHIEVEMENT TEST GRADE II, SAMPLE B, BOTH SEXES

N = 42

	Word Read	Para Mean	Total Read	Word Study	Weight	Height
OF	-16	-29+	-26	-14	-03	19
N	30	26	26	-03	-13	13
MO	06	05	06	22	-12	09
MC	-03	-04	-04	13	-05	00
RO	-13	-25	-23	-23	-14	20
RC	01	-01	01	-09	-06	25
OF+RO		-31*	-26		-13	-08
Weight	07	05	03	09		78
Height	-09	-05	-06	-01	78	

TABLE 9 b

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND STANFORD ACHIEVEMENT TEST GRADE II, SAMPLE B, BOYS

	Word Read	Para Mean	Total Read	Word Study	Weight	Height
OF	-06	-27	-28	-06	-22	-19
N	35	45*	43	39	-21	-69
MO	-02	-27	-22	04	-24	-10
MC	-05	-24	-16	07	-07	15
RO	-05	-34	-32	-42+	-25	03
RC	-22	-02	06	19	-19	-11
Weight	05	-14	-16	05	X	77
Height	-20	-10	-15	00	77	X

TABLE 9 c

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES
AND STANFORD ACHIEVEMENT TEST
GRADE II, SAMPLE B, GIRLS

N = 22

	Word Read	Para Mean	Total Read	Word Study	Weight	Height
OF	-08	-22	-19	18	11	38
N	18	-05	02	32	-21	37
MO	-05	26	17	-06	20	-08
MC	-05	26	14	-13	07	37
RO	06	09	08	39	20	39
RC	11	-08	-02	16	07	18
Weight	16	20	20	31		76
Height	-25	-42	-40	-17	76	

the other age/grade samples. In the male subsample a relationship shows up between RO and the Word Study test. In the same sample NC is related to Paragraph Meaning, however the direction of the relationship is inverted, i.e. higher fluctuation is positively related to better reading, a finding which is in contrast to the results in Grade II of Sample A. (Tables 9a,b,c).

Third Grade

The small sample of Grade III of Sample A, being the only representative of its age/grade level, shows nevertheless a conspicuous relationship between static balance ability and reading achievement, as measured by the Total Score of the Bond-Balow-Hoyt Reading Test (Upper Primary Level) (See Table 10). The relationship however turns out to be absolutely sex specific, in that in the female sample the correlation reaches the rather unusual size of -.85, whereas it drops to zero in the group of boys. Although this finding cannot be accepted as generally valid until verified by cross validation, it seems to link up with a similar pattern found in the relationship between OF and Teacher Evaluation in the Kindergarten sample and in the considerably higher correlations between static balance ability and reading in girls, which appear in the First grade of Sample B. These data may lead to assumptions about possible sex differences in the role of maturational/organismic factors in the causation of learning difficulties.

That is to say, it would appear that at the primary grades the girl's lower scholastic achievements would be more probably caused by deficient or retarded organismic maturation, whereas the boys learning problems would be more frequently the result of environmental and psychogenic conflict.

Ataxiametric patterns in educationally handicapped school children

Initially it was planned to examine a group of educationally handicapped first and second graders, placed in special classes. However, it turned out that the transfer of children with serious learning difficulties from regular to special settings occurs relatively late, so that the only available EH subjects in the school district where the study was carried out were at age/grade level III. This limited considerably the possibility to compare them with normal controls, as the only control group is our small sample of a single third grade with 21 Ss.

The 33 EH students, included in this study naturally belong to a large variety of clinical groups, so that no general description of their disturbances can be given except reference to their normal intelligence and to the necessity of having them transferred to special classes. It was also beyond the scope of this study to analyze the individual case histories of this sample, a method which

TABLE 10

CORRELATIONS BETWEEN ATAXIAMETRIC SCORES AND BAND-BALOW-HOYT READING TEST

GRADE III, SAMPLE A

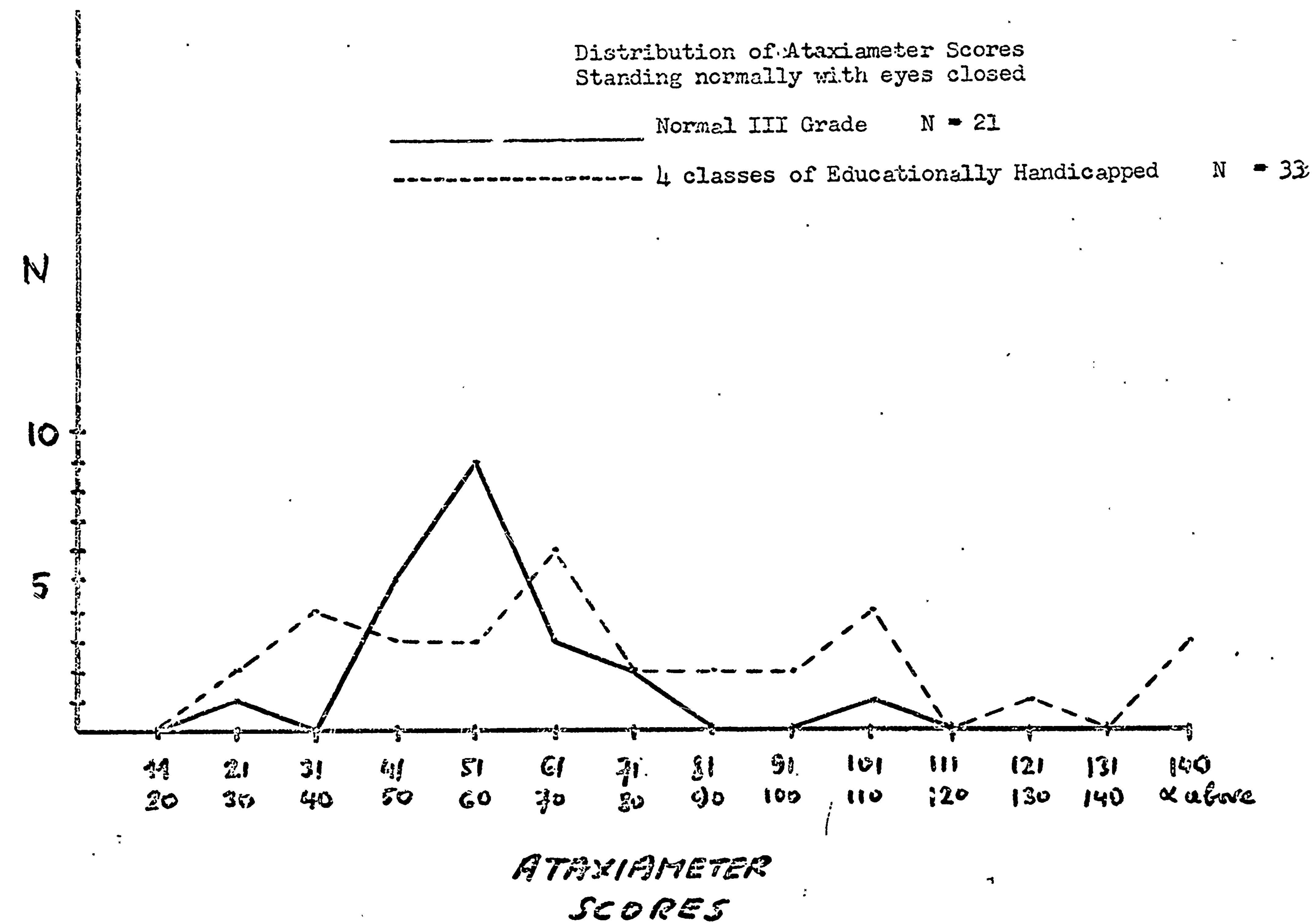
	BOTH SEXES N = 21				BOYS N = 12		
	Reading	Weight	Height	Reading W+H Elimin.	Reading	Weight	Height
OF	-38	04	23		00	05	07
NC	03	-11	54		-19	-10	53
MO	-14	20	08		-57	55	05
RC	-37	-02	18		-10	-20	-22
OF+NC +RC	-42+	-03	40	-62**	-07	-10	15
Weight	02		38		-46		34
Height	25	38			-53	34	

GIRLS
N = 8

	Reading	Weight	Height	Reading W+H Elimin.
OF	-94**	-45	07	-89**
NC	10	55	35	
MO	18	34	04	
RC	-68	-03	34	
OF+NC+RC	-88**	-18	28	-85**
Weight	41		71	
Height	-08	71		

FIGURE 3

Distribution of Ataxiameter Scores
Standing normally with eyes closed



would have possibly thrown more light on eventual relationships between educational handicap and static balance ability. Therefore our findings in respect of this group must be considered to be still very tentative.

As can be seen on Table 3, page 26 , the educationally handicapped girls are definitively inferior in their static balance ability when compared to age/grade mates of the same sex and even to those being one year younger. The differences are statistically not significant which might be due to the smallness of the sample (5 EH girls). It is also striking that the EH girls perform on a considerably lower level than the EH boys, whereas in the normal groups, girls are consistently superior to boys in static balance. This finding would be in line with our assumption, mentioned before, that learning difficulties in girls tend to be more maturationally and organismically determined than in boys.

As to the male EH, although they tend to be superior in "open eye" items (OF, MO), they show a definitively lower achievement on ataxiametric items with occluded vision (namely NC, MC and RC), however the differences are not significant. When data are more closely inspected, it turns out that the EH sample is characterized by a typical bimodal distribution of ataxiametric scores, with extreme positive deviations, in contrast to the normal distribution in the control group, as shown paradigmatically on Fig. 3. This seems to indicate that although the ataxiametric scores are apparently not detecting significant differences in static balance ability between normals and an undefined, heterogenous group of educationally handicapped, they differentiate within the population of the handicapped between balance impaired and balance not-impaired subjects, which may be of considerable diagnostic and therapeutic significance.

In addition, the balance impaired EH seem to be characterised by qualitatively deviant ataxiametric patterns, which have not yet been quantified and defined by our present, preliminary scoring method, but can be readily seen by visual inspection. (See Appendix specimen No. 5).

It is intended to investigate the issue of static balance impairment in educationally handicapped children in a new, specially designed project, based on systematic sampling of large EH populations.

Relationship between height and weight and ataxiametric scores

Although most of the correlations between height and weight and ataxiametric scores are low and seem to have a very limited impact on the investigated relationship between static balance ability and school readiness, it is worthwhile to overview the tendencies of their directionality.

TABLE 11

FREQUENCY DISTRIBUTIONS OF CORRELATION COEFFICIENTS BETWEEN AMPLITUDE, FLUCTUATION AND SYNCHRONY SCORES (OF, NC, RO, RC) AND WEIGHT AND HEIGHT.

	WEIGHT				HEIGHT		
Grade	Beyond -15	-15 to + 15	Beyond +15	Grade	Beyond -15	-15 to +15	Beyond +15
K	0	4	0	K	2	1	1
I	2	5	1	I	2	2	4
II	3	5	0	II	0	2	5
III	0	3	0	III	0	0	3

TABLE 12

LIST OF CORRELATION COEFFICIENTS BETWEEN WEIGHT DISPLACEMENT SCORES AND HEIGHT AND WEIGHT

	*MO WEIGHT	MO HEIGHT	MO WEIGHT	MC HEIGHT
K	-04	22	-05	15
I	-58;-26	-14;-21	-18	12
II	-09;-12	04;09	-05	00
III	20	08	-	-

*Left numbers within column refer to Sample A, right ones to Sample B.

As expected on the basis of physical law, weight tends to be correlated negatively and height positively with instability, as measured by the fluctuation and synchrony scores of OF, NC, RO and RC. In addition, the effect of weight seems to be considerably reduced by its function as denominator of the ataxiametric scores, and consequently its correlations with the latter are somewhat lower than those between ataxiametric scores and height. (See Table 11).

Besides, some developmental patterns emerge. Whereas the negative correlations with weight reach a peak at the first and second grades, the positive relationship with height steadily increases by age.

As to the percentage scores MO and MC, their correlations with **height** and weight are negligible, except for a tendency of MO to correlate negatively with weight at the first grade. (Table 12).

The correlational patterns presented on Table 11 are actually an indirect construct validation of the ataxiametric method.

If the ataxiametric scores would be strongly biased by either height or weight, their correlations with both of them would not only be high but also in the same direction, because height and weight in growing children are intimately intercorrelated and therefore the directions of their relationship with a third variable cannot diverge beyond a certain limit.

If these correlations are around zero and therefore "free" to diverge in the directions expected by physical law, there are strong indications that the ataxiametric scores predominantly measure what they are supposed to measure, namely the interaction of forces engaged in the maintenance of static equilibrium.

Patterns of intercorrelations between ataxiametric items

Although we are unable at this stage to carry out a factor analysis of the ataxiametric battery, it is of interest to analyze the patterns of intercorrelations between the ataxiametric items, taking into consideration their developmental aspects.* For this reason six separate matrices are presented on Tables 12 a - f, showing the intercorrelations of each item with the remaining ones throughout the age/grade groups of Samples A and B.

The general impression is, that intercorrelations between ataxiametric items are low, with the exception of an expectable high correlation between MO and MC. Another trend, which deserves attention is a substantial relationship between OF, RO

* Sex differences of intercorrelational patterns have not been elaborated at this stage of research, as they would relate to small samples where they would not be very meaningful.

and RC at grades one and two. Although these items are rather different in respect to placement of feet, size of support area and participation of vision, they seem to be similar as to their level of difficulty.

The Weight Displacement Scores MO and MC seem to be orthogonally related to Fluctuation and Synchrony scores, with the exception of possibly accidental relationships with NC in the Kindergarten sample and with OF and NC at grade two, Sample A.

RO and RC, although requiring an identical foot position are not intercorrelated, which seems to indicate that the occlusion of vision is a rather decisive factor in this more difficult posture. This is in contrast to the high intercorrelation between the considerably easier postures MO and MC.

NC is characterized by inconsistent correlations not only when age groups are compared, but even within the same age/grade group between samples. This may be due to a low reliability, either of the item itself or its still inadequate scoring method. It will be remembered that this item is the only one to measure left-right weight displacements.

The generally low intercorrelations between OF and MO in the light of the good correlations of each of them with the external criterion of reading skill at Grade I seems to represent a promising base for the future construction of an ataxiametric "reading readiness" battery.

The general picture of these patterns seems to indicate that our present ataxiametric measures have three dimensions:

a) High stress (OF, RO, RC) vs. low stress (NC);

b) Fluctuation and Synchrony (OF, RO, RC, NC) vs. Weight Displacement Percentage (MC, MC);

c) Participation vs. Occlusion of vision (RO vs. RC).

TABLE 13 a

INTERCORRELATIONS BETWEEN ATAXIAMETRIC ITEMS

	GRADE	NC	MO	MC	RO	RC
	KI	00	-11	11	27	25
	IA	56	-08	-	56	60
OF	IB	26	-16	-14	19	37
	IIA	36	-41	-	-	51
	IIB	15	09	10	46	23
	III	48	09	-	-	18

	GRADE	OF	MO	MC	RO	RC
	KI	00	54	31	40	-02
NC	IA	56	-11	-	38	59
	IB	26	02	01	-09	09
	IIA	36	31	-	-	29
	IIB	15	-07	-01	11	04
	III	48	20	-	-	21

TABLE 13 b

INTERCORRELATIONS BETWEEN ATAXIAMETRIC ITEMS

(continued)

	GRADE	OF	NC	MC	RO	RC
	KI	-11	54	72	15	09
	IA	-08	-11	-	-19	-13
MO	IB	-18	02	47	-01	00
	IIA	-41	31	-	-	07
	IIIB	09	-07	76	02	04
	III	09	20	-	-	18

	GRADE	OF	NC	MO	RO	RC
	KI	11	31	72	04	15
MC	IA	-	-	-	-	-
	IB	-14	01	47	14	-05
	IIA	-	-	-	-	-
	IIB	10	-01	76	03	13
	III	-	-	-	-	-

TABLE 13 c

INTERCORRELATIONS BETWEEN ATAXIAMETRIC ITEMS

(continued)

	GRADE	OF	NC	MO	MC	RO
	KI	27	40	15	04	18
	IA	56	38	-19	-	-13
RO	IB	19	-09	-01	-14	18
	IIA	-	-	-	-	-
	IIB	46	11	02	03	25
	III	-	-	-	-	-

	GRADE	OF	NC	MO	MC	RO
	KI	25	-02	09	15	18
RC	IA	60	59	-19	-	13
	IB	37	09	00	-05	18
	IIA	51	29	07	-	-
	IIB	23	04	-04	13	25
	III	18	21	18	-	-

DISCUSSION

Discussing our findings, it must be borne in mind that this study is a first attempt to explore relationships between two performances, which are considered to belong to two very different and mutually remote functional areas of the human personality and which differ widely as to their temporal dimensions. The ataxiametric scores measure tasks of 15, 20 and 30 seconds, the time required for the longest item sequence used as a composite score (OF + MO + RO), being 65 seconds. These scores have been found to correlate significantly with achievement tests, which have administration times between 15 minutes to one hour, not speaking of the Kindergarten Teacher Questionnaire based on long range observation. This fact alone seems to indicate that the ataxiametric scores reflect neurophysiological and reflex-level roots of mental responses, these roots being fundamentally different from the molar samples of intellectual and social interaction which are the essence of mental tests. In other words, whereas intelligence or achievement tests predict a certain universe of mental responses by virtue of the former being a representative sample of this same universe, the ataxiametric battery seems to possess predictive power because it eventually measures basic organismic processes underlying these responses. If this will be further substantiated by future research, new avenues of approach may be laid open to detect the causal relationships between neurophysiological maturation (or learning on neurophysiological level) and basic mental processes which play an important role in the attainment of cognitive (and possibly also social) school readiness.

This basically theoretical aspect of our results must be strictly held apart from their pragmatic implications, consisting in the eventual power of the ataxiametric scores to predict learning failures at the first grade, or to increase essentially the predictive validity of already existing school readiness inventories.

Our results seem to indicate that between 30 to 60% of learning difficulties at the lower elementary grades might be attributed to organismic/maturational processes reflected by the ataxiametric scores, which thus might provide cues to discriminate between predominantly emotional-social and neurological-maturational learning handicaps. (As already mentioned, girls seem to have a stronger disposition towards the latter).

It should be added immediately, that the detection and definition of neurophysiological causes of learning difficulties does not imply that this type of school failure should be considered to be "predetermined," "constitutional" or "hereditary" and therefore much less reversible than lag in scholastic achievements caused by psychogenic or socio-cultural factors. The reverse might be true: An emotional learning disturbance might turn out to be much more resistant to treatment than a reading difficulty related to organismic factors, as the latter may be attacked by straightforward, systematic and intensive physical training or physiotheraphy.

As to the substance of our findings, it seems that the most striking and consistent relationship between mental and ataxiametric variables is shown by OF. It correlates with teacher observation and aritnmetic school-readiness at the Kindergarten level and with two different well standardized and widely used reading tests in 5 independent samples of first, second and third graders. Its test-retest reliability is .67. Its additional advantage is a negligible correlation with weight and height. It thus seems promising to develop more items of this type and to assemble them into sequences of "balancing with heavy concentration of weight on a small supporting area."

RO seems to be functionally close to OF but appears to predict a wider spectrum of scholastic achievements than OF, including numerical and perceptual tasks, besides being sensitive to sex differences in the relationships between balance ability and cognition.

MO turns out to have considerable predictive validity, which however is limited to the first grade. This is remarkable, as this item does not show any systematic progress by age and in boys even tends to regress gradually, albeit insignificantly. (See Table 3 on page 26). It should also be remembered that it tends to correlate negatively with weight at the first grades (See Table 12 on page 54) which is exactly the developmental period during which it correlates significantly in positive direction with school readiness.

We propose the following tentative interpretation of these findings: The typical growth spurt occuring at school entrance age (See p. 36) is probably a considerable challenge to static balance ability which seems initially to respond to the intensified weight and height increase by "leaning forward" as a "security measure." (See p. 14). This would show up in a forward weight displacement, and thus in a negative correlation between weight and MO. However, the child with better balance ability, supposed to be also the mentally advanced, copes earlier and easier with this "developmental challenge" by regaining a more secure posture "in spite of growing fast," which is manifest in backward weight displacement (i.e. a higher MO) and hence the positive correlation between MO and mental tests.

In contrast to the "open eye" items, the tasks involving occluded vision seem to be relatively less and less consistently related to cognition in normal populations. MC, except for a nearly significant relationship with the Metropolitan Copy subtest in first grade boys of Sample B is unrelated to all criterion variables. (It has not been given to Sample A). RC tends to be related to visual perception as indicated by its relationship with the Bender and Metropolitan Match subtest and to overall school readiness as evaluated by the Kindergarten teacher. Whilst unrelated to the Stanford Achievement Tests, it correlates with the Bond-Balow-Hoyt total reading scores at grades two and three of Sample A. Whether this inconsistency is due to unreliability or to structural differences between the two reading tests is a matter of speculation. RC seems also to be sensitive to differences between normal and educationally handicapped children, especially girls.

NC shows the most inconsistent relationships. It is nearly significantly related to reading in the first and second grades of Sample A, but not at all in Sample B. It tends to correlate in inverted direction (i.e. higher fluctuations related to higher scores) with school readiness in the Kindergarten, and in boys of Sample B with the Word Study subtest at grade one and with the Paragraph Meaning subtest at grade two.

On the other hand it discriminates (in expected direction) between normals and educationally handicapped.

As already mentioned, the scoring method of this item might still be inadequate. It will be also noted that NC tends to correlate substantially with weight and height, albeit in inconsistent directions. Consequently it may be oversensitive to height and growth spurts which in turn may be related to mental development and hence the fluctuations of relationships between NC and the criterion variables.

Summing up our findings it may be stated that the main hypothesis of the study has been supported and that static balance ability as measured by electronic ataxiametry is substantially related to school readiness and reading achievement. Two independent samples of first graders produce the most convincing and reliable evidence. In the Kindergarten and the second grades results are in line with the hypothesis, but less pronounced and consistent.

In the single group of third graders only girls show a highly significant correlation between balance ability and reading, a finding which together with parallel trends in other parts of the sample seems to indicate that scholastic achievement and failure in girls is more intimately related to organismic and maturational factors. In a small population of Educationally Handicapped the ataxiametric scores tend to dichotomize the population into balance-impaired and balance-unimpaired subjects. Thus, the general impression seems to be that the ataxiametric method, although still in a stage of pilot experimentation, promises to open new avenues of approach to the basic and universal problems of learning difficulties emerging at school entrance and at the lower grades of elementary education.

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APPENDIX I

SPECIMEN OF ATAXIAMETRIC RECORDS

POSTURE: Standing normally with eyes blindfolded (NC)

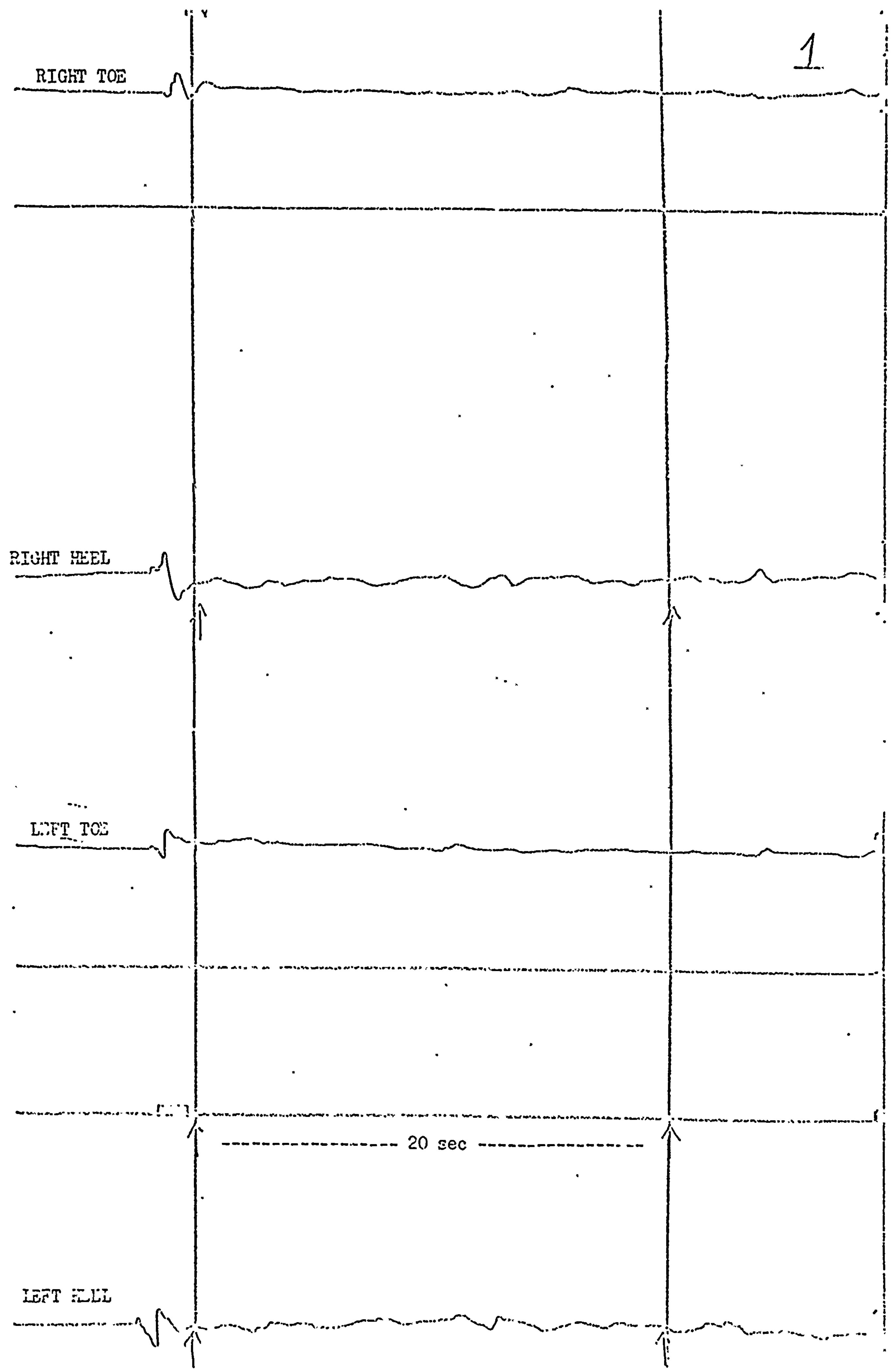
1 Good reader, grade one, normal class

2 Good reader, grade one, normal class

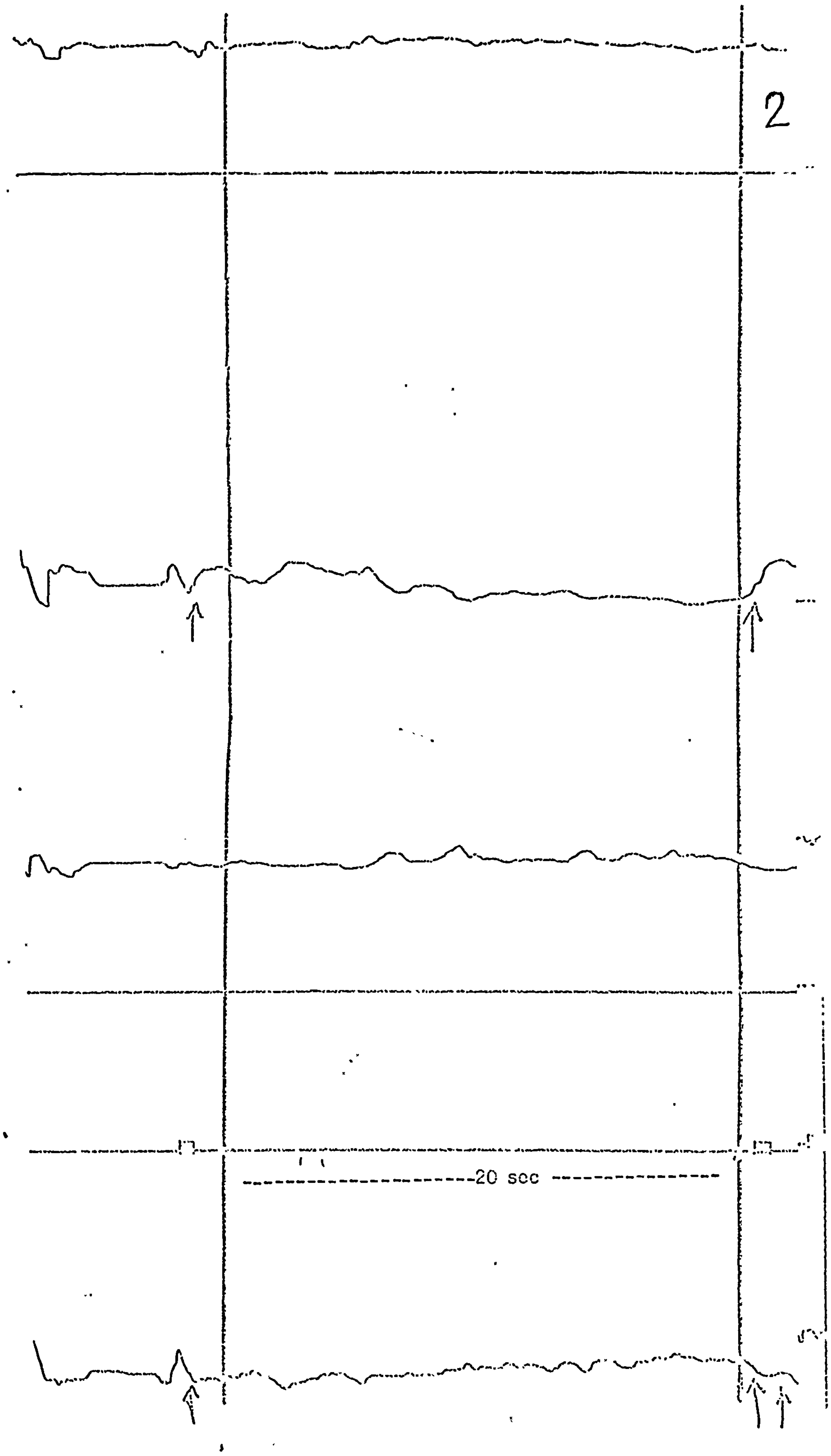
3 Bad reader, grade one, normal class

4 Worst reader of his class, grade one, normal class

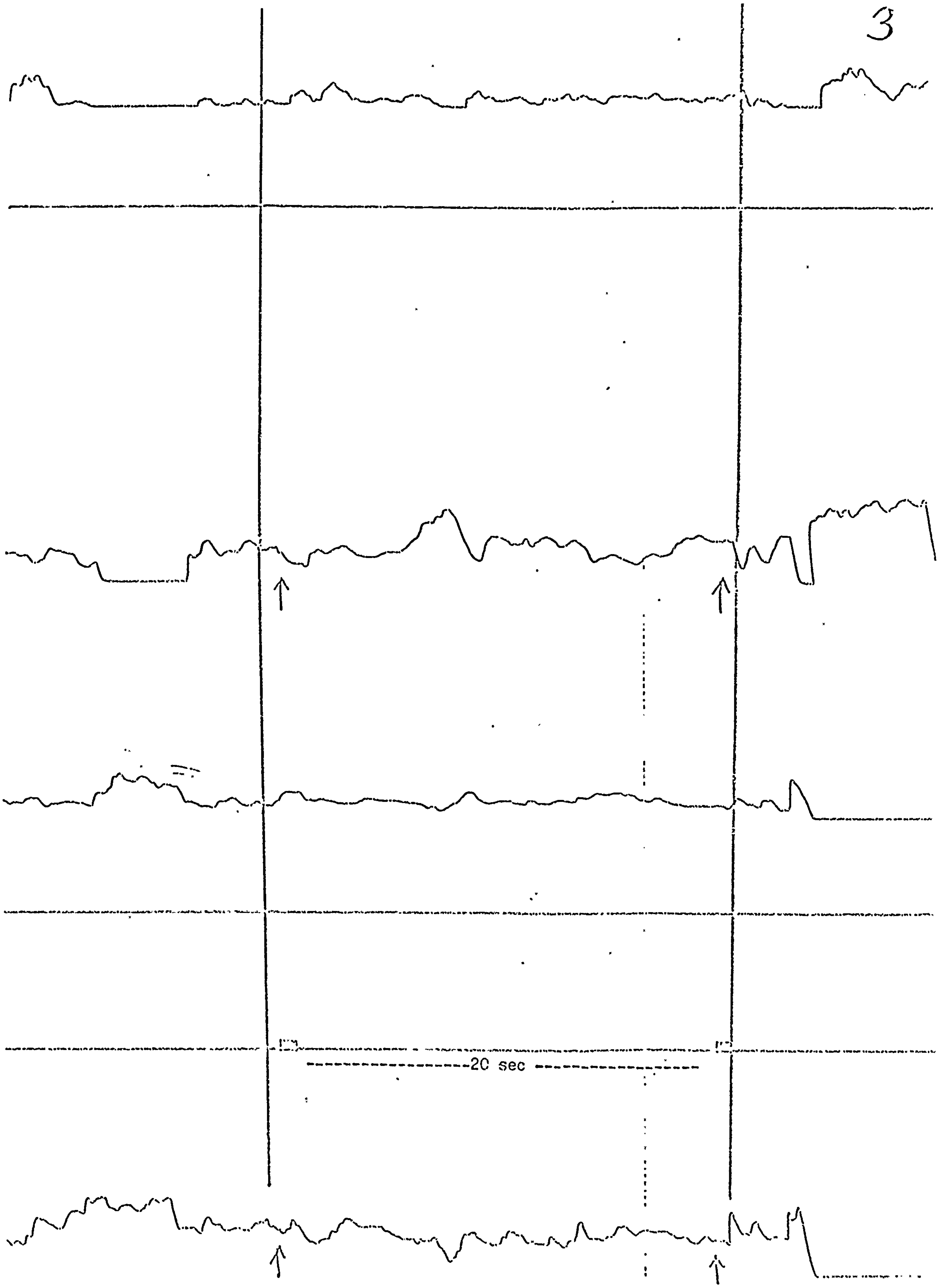
5 Girls in class for Educationally Handicapped



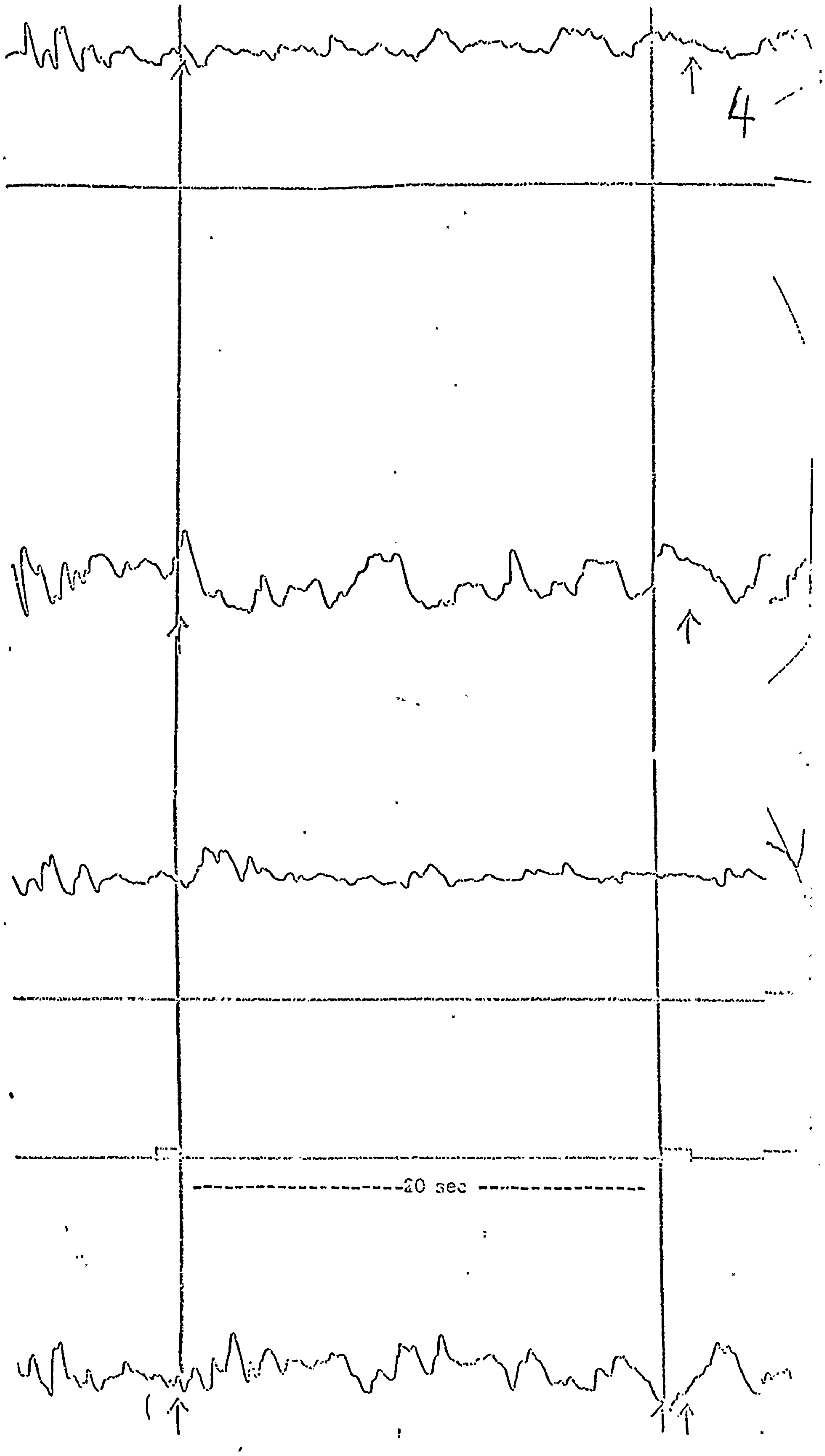
Good reader



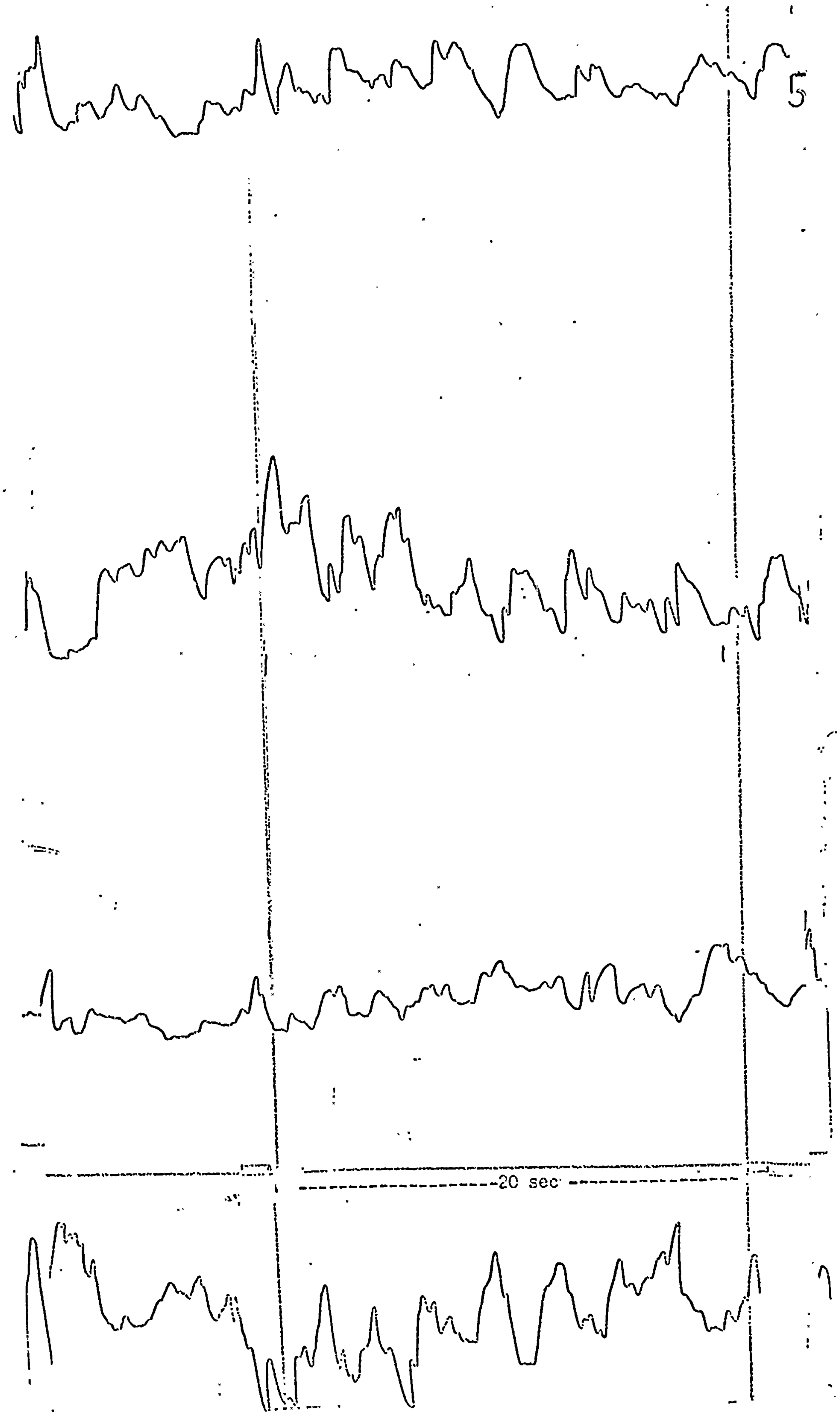
Good reader



Bad reader



Worst reader of his class



Educationally Handicapped child

APPENDIX II

KINDERGARTEN TEACHER OBSERVATION INVENTORY

TEACHER's OBSERVATION SUMMARY OF SCHOOL READINESS

2021

by Zipporeth Kohen-Raz, M.A.
School Guidance Clinic
Municipality of Jerusalem

RESTRICTED RESEARCH FORM

Name.

CASE NO. 1. FAIR SCHOOL READINESS

1. CHILD's APPEARANCE.

a. very neat and clean b. does not care about his appearance

c. unclean and untidy

2. HEALTH

Absence from kindergarten due to illness: a)frequent b) regular c) rare.

3. PHYSICAL CHARACTERISTICS

a. physical handicaps........none - good physical coordination........

b. conspicuous motor retardation

c. clumsy

d. motorically normal

e. motorically developed and versatile

4. BEHAVIOUR UPON ARRIVAL AT SCHOOL good -

a. separates easily from accompanying person

b. Reluctant to separate

c. Tries to run away (Does he turn immediately to some occupation or does he need encouragement?)

....

5. ATTITUDE TOWARDS TEACHER

a. a. hostile b. detached & reserved c. normal d. seeks attention e. clings

6. SPONTANEITY IN RELATIONSHIP WITH TEACHER

low 1...2...3...4...5..high

7. OBEDIENCE

disobedient 1..2..3..4..5 very obedient

8. CONSISTENCY IN ATTITUDE TOWARDS TEACHER

inconsistent 1...2...3...4...5 very consistent

9. BEHAVIOUR DURING PLAY

a. prefers solitary play b. drifting c. ordinary play d. shows leadership

play behaviour adapts himself 1...2...3...4...5 disturbd

is constructive 1...2...3...4...5 destructive

10. PREFERRED GAMES

specify

-Does he play games typical for the other sex? no

11. ACTIVITIES

	Level				Quality				
	iniative	persistent	sporadic	must be pushed	A	B	C	D	E
Drawing	1 ✓ ...	...	...	...	.	.	.	.	.
Clay	✓ ...	....	...	...	.	.	.	.	.
Paper, cardboard etc	...	...	1 ✓ ...	...	.	.	.	.	.
Music	...	...	...	1 ✓ ...	.	.	.	.	.
Dramatic play	...	...	...	✓ ...	.	.	.	.	.
Dance	...	...	...	1 ✓ ...	.	.	.	.	.
	2		1	3					

12. CONCENTRATION

a. unable to concentrate b. attaentive at times c generally attentive

d. concentrates easily

13. STORY REPRODUCTION

a. unable to reproduce b. reproduces in a confuse manner

c. reproduces failry well d. reproduces fluently and correctly

14. LINGUSTIC EXPRESSION

a. Vocabulary: poor - fair - rich

b. Semantic correctness: poor - fair - good

15. THOUGHT PROCESS excellent if he listens

a. Is he able to draw the correct conclusions in the context of a story and in the context of an everyday situation?

b. Does he demonstrate imaginative activity (such as story invention?)

c. Is there evidence of unrealsistic thought and some daydreaming?

How much in percentages a.......b.....c.....

16. MOOD & TEMPARAMENT

a. sensitivity very sensitive 1..2..3..4..5 dull

b. emotional stability unstable...1..2..3..4..5 very stable

c. typical mood very sad 1..2..3..4..5very happy

d. self confidence insecure 1..2..3..4..5exaggerated self confidence

17. SOCIAL RELATIONSHIP

a) rejected by peers 1..2..3..4..5 accepted as leader

b) participation in group activities

does not respond 1..2..3..4..5very responsive, volunteers to tasks

c) selfish 1..2..3..4..5 generous

18. SYMPTOMS none N never S sometimes O often A always
? not known

Finger sucking......nails biting........stammering......wetting.....

soiling....masturbation.....tics........other

19. ESTIMATION OF SCHOOL READINESS

not at all 1..2..3..4..5 definitively

Specify in which respect ....
Good academic ability but does not pay attention as he should. Also has a very "cold" reaction to anything he does not wish to respond to.

empty page

TEACHER's OBSERVATION SUMMARY OF SCHOOL READINESS

by Zipporeth Kohen-Raz, M.A.
School Guidance Clinic
Municipality of Jerusalem

RESTRICTED RESEARCH FORM

Name.

CASE NO. 2. POOR SCHOOL READINESS

CHILD RECOMMANDED TO STAY IN K-G.

1. CHILD's APPEARANCE.

a. very neat and clean   b. does not care about his appearance

c. unclean and untidy

2. HEALTH

Absence from kindergarten due to illness: a)frequent b) regular c)rare.

3. PHYSICAL CHARACTERISTICS

a. physical ahndicaps.... Speech ....

b. conspicuous motor retardation

c. clumsy

d. motorically normal

e. motorically developed and versatile quite good.

4. BEHAVIOUR UPON ARRIVAL AT SCHOOL good

a. separates easily from accompanying person

b. Reluctant to separate

c. Tries to run away   (Does he turn immediately to some occupation or does he need encouragement?)

....

5. ATTITUDE TOWARDS TEACHER

a. a. hostile b. detached & reserved c. normal d. seeks attention e. clings

6. SPONTANEITY IN RELATIONSHIP WITH TEACHER

low 1...2...3...4...5..high

7. OBEDIENCE

disobedient 1..2..3..4..5 very obedient

8. CONSISTENCY IN ATTITUDE TOWARDS TEACHER

inconsistent 1...2...3...4...5 very consistent

9. BEHAVIOUR DURING PLAY

a. prefers solitary play b. drifting c. ordinary play d. shows leadership

play behaviour adapts himself 1...2...3...4...5 disturbs

is constructive 1...2...3...4...5 destructive

10. PREFERRED GAMES

specify

Does he play games typical for the other sex? no

11. ACTIVITIES

	Level				Quality				
	iniative	persistent	sporadic	must be pushed	A	B	C	D	E
Drawing	...	...	✓	...	.	.	.	.	.
Clay	...	....	✓	...	.	.	.	.	.
Paper, cardboard etc	✓	...	...	...	.	.	.	.	.
Music	...	...	✓	...	.	.	.	.	.
Dramatic play	...	...	...	✓	.	.	.	.	.
Dance	...	...	...	✓	.	.	.	.	.

12. CONCENTRATION

a. unable to concentrate b. attaentive at times c generally attentive

d. concentrates easily

13. STORY REPRODUCTION

a. unable to reproduce b. reproduces in a confuse manner

c. reproduces failry well d. reproduces fluently and correctly

14. LINGUSTIC EXPRESSION

a. Vocabulagy: poor - fair - rich

b. Semantic correctness: poor - fair - good

15. THOUGHT PROCESS

a. Is he able to draw the correct conclusions in the context of a story and in the context of an everyday situation? - needs encouragement

b. Does he demonstrate imaginative activity (such as story invention?) does not have long enough interest span

c. Is there evidence of unrealsistic thought and daydreaming? yes

How much in percentages a.......b.....c.....

16. MOOD & TEMPARAMENT

a. sensitivity very sensitive 1..2..3..4..5 dull

b. emotional stability unstable...1..2..3..4..5 very stable

c. typical mood very sad 1..2..3..4..5very happy

d. self confidence insecure 1..2..3 .4..5exaggerated self confidence

17. SOCIAL RELATIONSHIP

a) rejected by peers 1..2..3..4..5 accepted as leader

b) participation in group activities

does not respond 1..2..3..4..5very responsive, volunteers to tasks

c) selfish 1..2..3..4..5 generous

18. SYMPTOMS none N never S sometimes O often A always
? not known

Finger sucking......nails biting.......stammering......wetting.....

soiling....masturbation.....tics........other

19. ESTIMATION OF SCHOOL READINESS

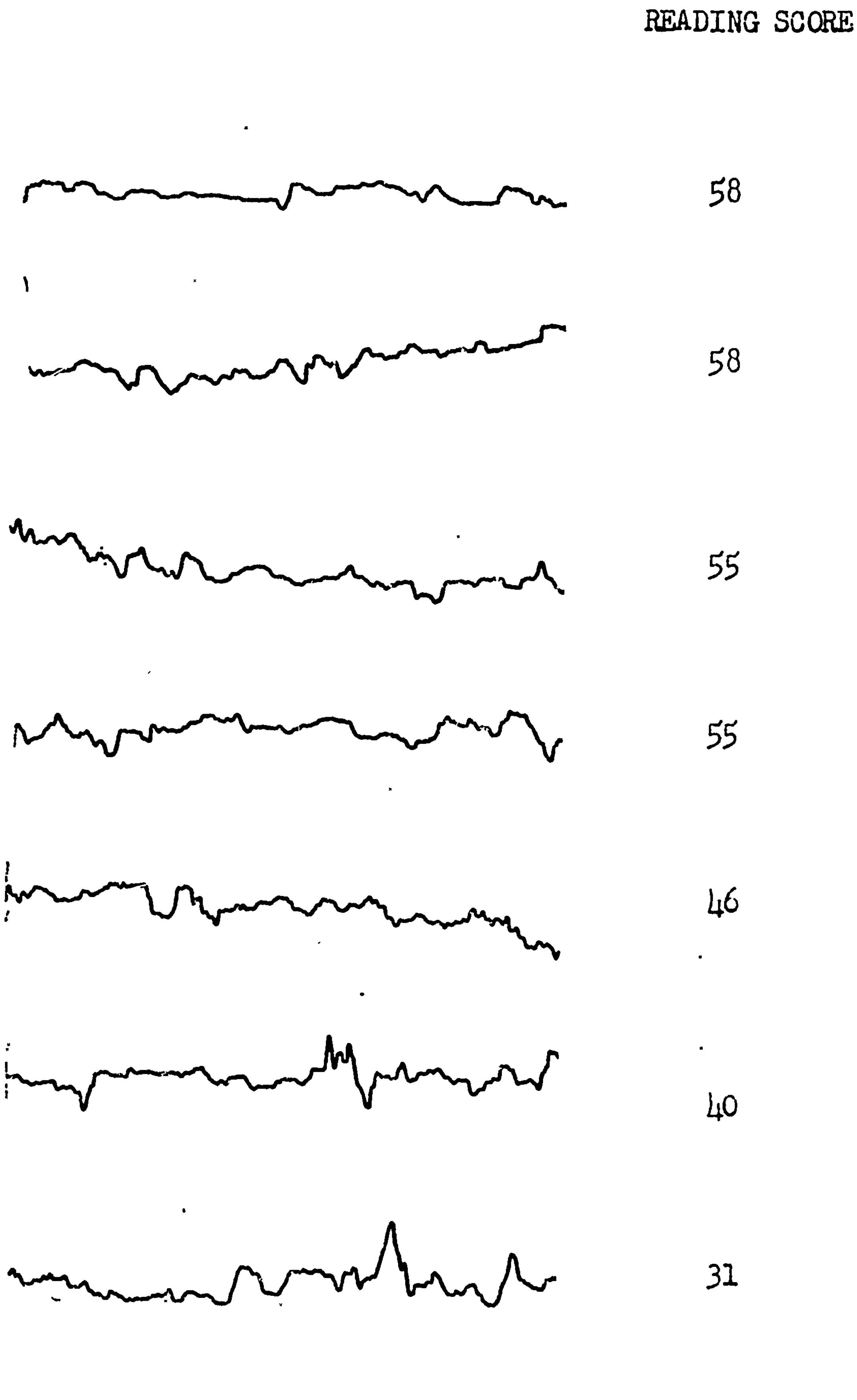
not at all 1..2..3..4..5 definitively

Specify in which respect ....
I am holding Steve back
because of emotional immaturity that
effects his academic work. He has had
to make too many adjustments this year.

APPENDIX III

ORIGINAL DATA ON 8 GIRLS/GRADE III/SAMPLE A YIELDING CORRELATION OF .94 BETWEEN OF AND READING SCORES ON TABLE 10. GRAPHS ARE THE INDIVIDUAL RECORDS OF THE LEFT HEEL WHILST STANDING ON LEFT FOOT WITH EYES OPEN. ON PAGE 85 SAME RECORDS OF THE 5 EDUCATIONALLY HANDICAPPED GIRLS INCLUDED IN THE SAMPLE.

8 NORMAL GIRLS



5 ED.HAND. GIRLS